THE PROGRESSIVE FISH CULTURIST

NEWS AND VIEWS FROM MANY SOURCES ON PRACTICAL HATCHERY PROBLEMS

ISSUED BY THE

U. S. DEPARTMENT OF COMMERCE

HARRY L. HOPKINS, *SECRETARY*

BUREAU OF FISHERIES

CHAS. E. JACKSON, *ACTING COMMISSIONER*

MAY - JUNE 1939

WASHINGTON

THE PROGRESSIVE FISH CULTURIST

A SERIAL memorandum published occasionally for the advancement of Federal, State, and private fish culture and fishery management in fresh waters.

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(Continued inside back cover)

9596

Washington D.C
Jan 22d/64.

Dear Sir

I am desirous of ascertaining what foreign fishes could be introduced into the fresh waters of this country with the view of improving the alimentation of the people. - as in China

Whether the Carp has been successfully propagated in the U. States and whether you deem it feasible to import the Gouramis which is domesticated in China & Japan.

I propose a bureau of Pisiculture to restock many of our rivers &c - and would be obliged for any information and suggestion you may be pleased to offer

Very respectfully
A C Hamlin
A Col & Med Insp
U S Army

Theo. Gill. Esq

26. La. Avenue

This letter addressed to Dr. Theodore Gill, Smithsonian Institution, by Col. A. C. Hamlin on January 22, 1864, containing the suggestion of a "bureau of pisiculture", is probably the first move toward the establishment of a Bureau of Fisheries in the United States.

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Memorandum I-131 Washington, D. C. May-June 1939 No. 45

THE SUCCESS OF THE BONNEVILLE FISHWAYS DURING THEIR FIRST YEAR OF OPERATION

By Harlan B. Holmes, Aquatic Biologist, and
Frederick G. Morton, Inspector, Fishway Operations
Corps of Engineers, U. S. Army

EARLY IN 1938 the U. S. Engineers completed the Bonneville Dam in the gorge of the Cascades about 100 miles above the mouth of the Columbia River. The dam consists of two units, a power house unit 600 feet long, and a spillway unit 1200 feet long, raising the water level 35 feet at high stages of the river and 63 feet at low water stages. On February 14, the river level above the dam was raised so that water started flowing through the permanent fish ladders that had been provided for the protection of the valuable runs of salmon. Since that time the runs of fish for a full year have passed the dam, thus permitting an appraisal of the success of the fishways.

Owing to the magnitude of the fish runs involved and the publicity that the problem of fish protection has received during the four years of construction, everyone who is interested in fish conservation has looked with keen interest to the results of this first year of operation. Those who have been required to rely upon newspaper and magazine comments have found decidedly conflicting reports. Among the thousands of people who visited Bonneville Dam during the summer, probably the majority saw few, if any, fish, and many of these visitors went away with a feeling of doubt regarding the success of the fishways.

Editor's Note: In the early stages of designing the Bonneville Dam, Mr. H. B. Holmes, Associate Aquatic Biologist of the U. S. Bureau of Fisheries, was detailed, at the request of the War Department, to conduct studies of fish protection. Later he was officially transferred to the Corps of Engineers and has remained until the present

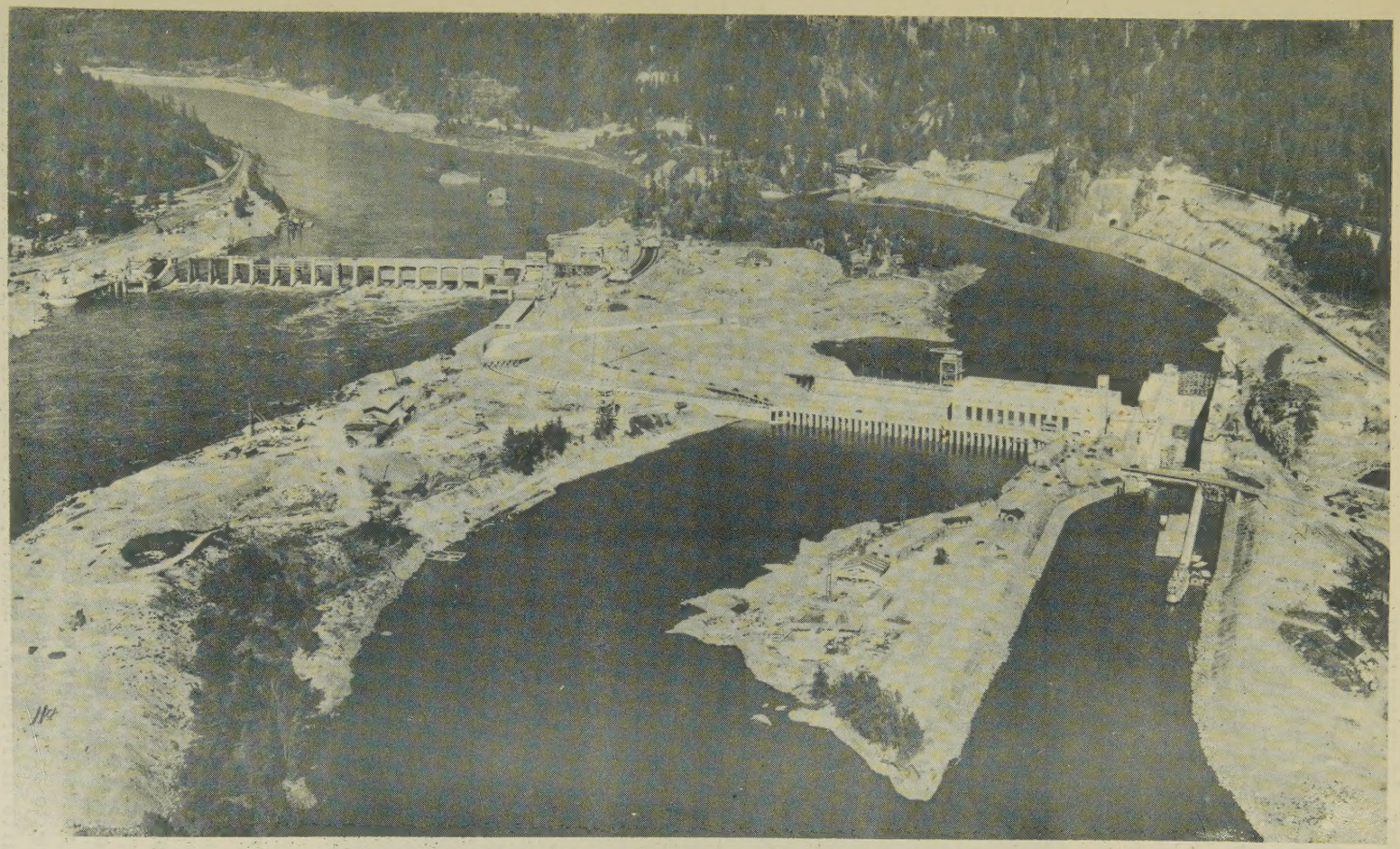
time in charge of fishery studies and as advisor on fishway operation. He is, therefore, primarily responsible for the basic designs embodied in the fish protective devices which cost upwards of $3,700,000 to construct and require nearly a score of men to operate. Associated with him during the earlier period of study were Mr. Henry F. Blood, Hydraulic Engineer of Portland, Oregon, and Mr. Milo C. Bell, Engineer of the Fishery Department of the State of Washington, the latter representing an advisory committee of the States of Oregon, Washington, and Idaho. Officers and employees of the Engineer Corps also contributed to the design of the fish protective works, particularly in the more technical engineering studies and in developing novel mechanical features required in applying the basic designs. Since these fishways, including the fish ladders and fish locks, popularly called "elevators", embody many improvements on the usual practices in this field which are covered by Government patents, the entire system of fish protective works at Bonneville may properly be designated as the "Holmes Fishways."

To the experienced observer, especially to those who have been responsible for the design and operation of the fishways, this failure to observe great numbers of fish has been one of the greatest sources of satisfaction. The continuous absence of any accumulation of fish below the dam gave assurance that the fish were passing as rapidly as they reached the obstruction. The experienced observer, further, is not disturbed by failure to observe significant numbers of fish in the ladders. The individual pools of the ladders, each having a surface area of 40 feet by 16 feet and a depth of 6 feet, give ample space for the fish to rest and to maneuver for the climb of only one foot to the next higher pool. It is decidedly the exception, rather than the rule, for a fish to jump clear of the water. A large proportion of the fish swim through the two-foot-square submerged opening that is provided in each of the partitions between pools. The fish that pass over the partitions usually swim through the sheet of water which overflows this partition, seldom breaking the surface.

Fish Counting

Fortunately, it has not been necessary to base conclusions as to the success of the fishways upon this negative type of circumstantial evidence. Each fish is identified, counted and recorded as it passes the upper end of the ladder. The counting stations consist of picketed barriers which block the passage of fish. In each barrier are three gate-controlled openings two feet wide through which fish may be permitted to pass. To facilitate the identification of the species of fish, there is a submerged, white platform over which the fish must pass as they leave the counting gate. The gates are opened only while an observer is on duty to tally the number of each species of fish on mechanical recording machines.

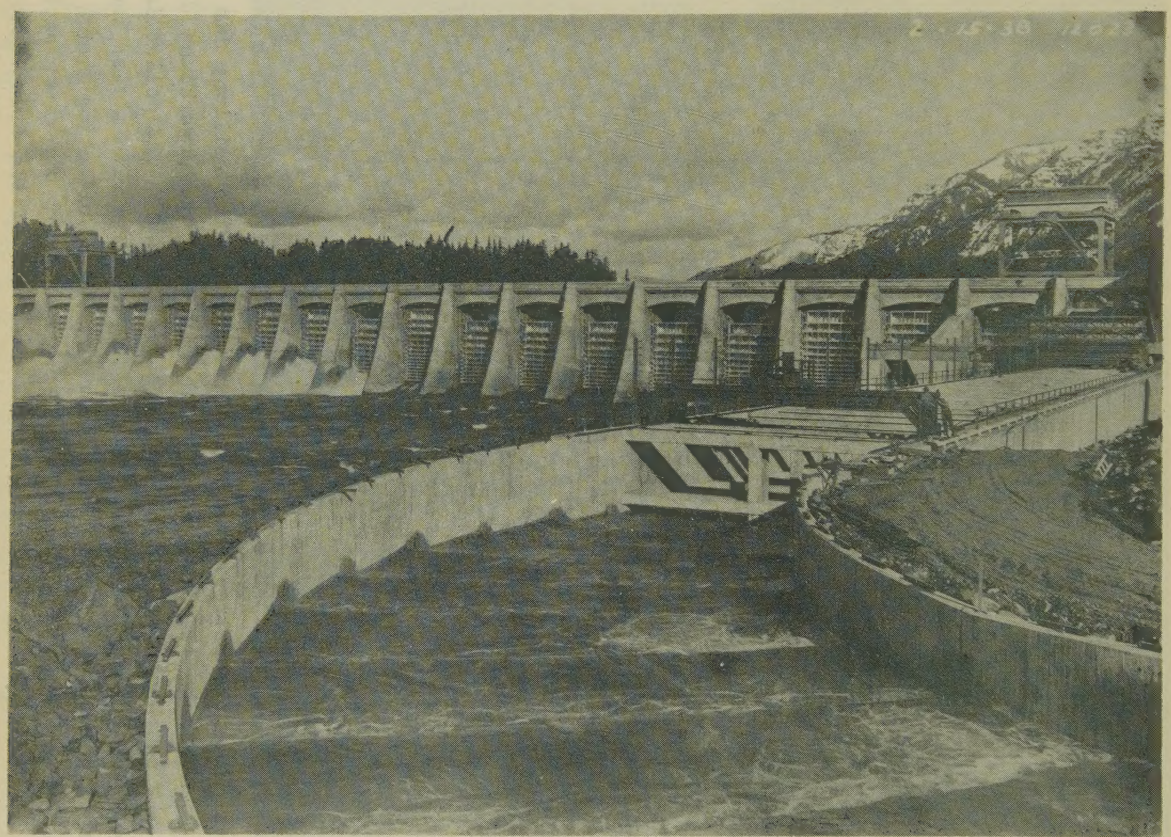
The counting stations were installed on May 7, 1938, since which time a complete record has been maintained of all species. No doubt there have been minor errors in identification of species, especially among the so-called scrap fish, such as suckers, chubs, and squaw fish. Otherwise, the counts are substantially exact except in the case of the lamprey (eels), whose slender form permits many of them to pass through the one-inch picket openings adjacent to the counting gates. The count



The Bonneville Dam (looking upstream) during construction. The spillway dam extends from Bradford Island (center) to the Washington shore (left). The powerhouse dam and navigation lock span the south channel to the Oregon shore (right). The collecting trap (vertical openings) extends across the powerhouse dam and connects with a fish ladder crossing the island at its left end and with locks at its right end. Collecting traps, ladders, and locks are located at each end of the spillway dam. Height of the water back of the completed structure is indicated by the end of the center arm of the fish ladder on Bradford Island which opens into the forebay. Photo by U. S. Engineers.

of lampreys, however, is unimportant.

Throughout the greater part of the season one counting gate in each ladder was operated for 16 hours a day. The counter usually observed continuously for about three-quarters of each hour, taking the remainder of the hour off to record the counts and to rest his eyes from the confining task of looking continuously into the water. The procedure of counting for only 16 hours a day and leaving the gates closed at



Fish ladder on Bradford Island at the south end of the spillway dam.

night was based upon a general knowledge of reduced activity of salmon at night. This condition was verified by counting two nights a week. It was found that an average of about 4 percent of the salmon would pass during the 8 hours at night, and it was observed that no unfavorable condition was created by forcing this small proportion of the fish to wait until daylight to continue its migration. Some of the scrap fish react quite differently. Suckers, for example, are less active during the middle of the day and more active at night. Night counts represented about 14 per-

cent of that species. In the case of lamprey, about a half of the run passed during the 8-hour period at night.

For a period of about two weeks in September, at the peak of the run, when the daily counts of salmon and trout ranged from ten to twenty thousand fish, a second gate at each counting station was operated through the middle of the day and counting was continued through the night. As the runs dropped off and the days became shorter, counting time was reduced until finally fish passage was permitted through only one gate at a time, one man making all the observations, by alternating between the two counting stations. In order to secure a complete record, counting has been continued regularly on this basis although the runs have decreased to as low as 45 salmon and trout for the entire month of January.

The counts of the principal species are summarized in the accompanying table:

NUMBERS OF FISH COUNTED AT THE BONNEVILLE FISHWAYS

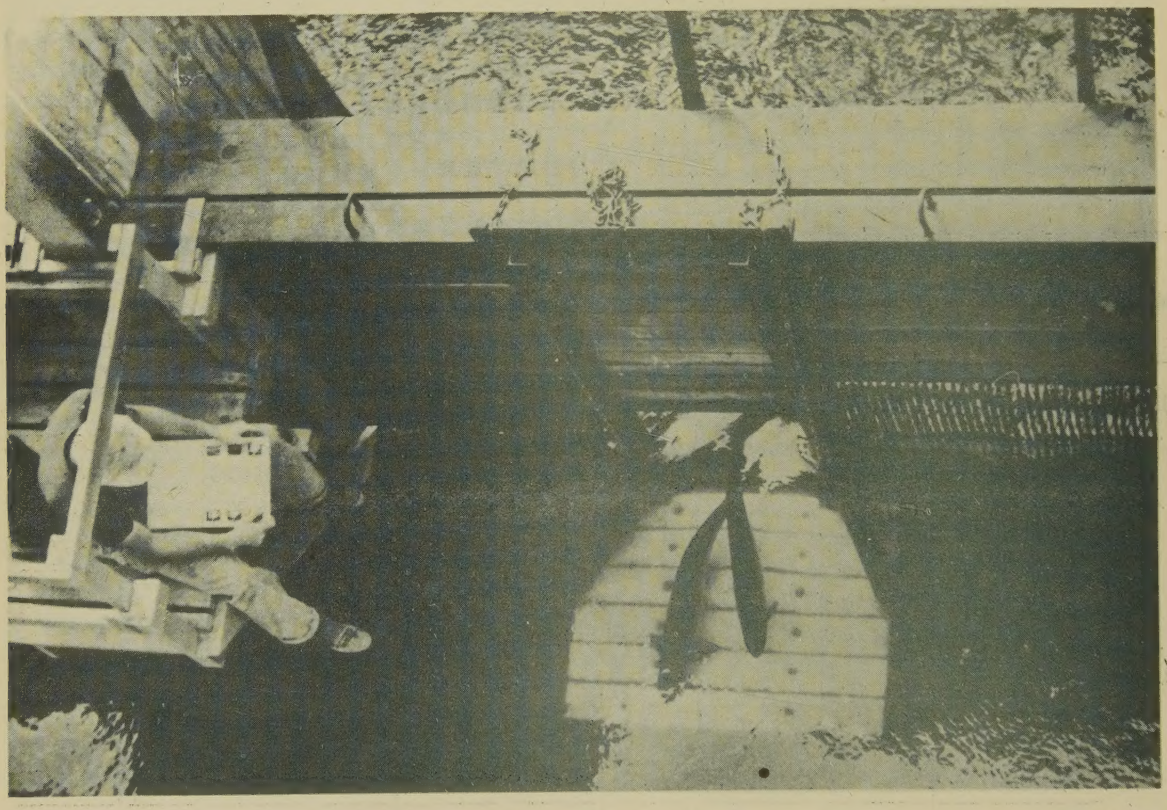
DURING THE FIRST YEAR

Month	Species								
	Chinook Salmon	Blueback Salmon	Silver Salmon	Chum Salmon	Trout	Shad	"Scrap Fish"	White Fish	Lamprey
1938 May	22,371	1,025	.....	.....	6,633	.....	39,694	16	7,502
June	8,221	17,811	.....	.....	2,409	39	97,842	46	23,831
July	6,556	53,864	.....	.....	19,493	3,185	167,829	56	130,818
Aug.	34,765	2,097	3,070	.....	29,905	1,502	37,907	315	60,821
Sept.	197,294	235	10,995	.....	47,619	527	21,788	563	4,462
Oct.	2,302	6	972	1,245	2,589	21	8,377	1,281	172
Nov.	263	2	141	799	466	.....	632	690	19
Dec.	27	.....	7	73	105	.....	.....	155	2
1939 Jan.	6	.....	3	2	34	.....	.....	71	.....
Feb.	12	.....	.....	.....	22	.....	.....	.....	.....
Mar.	121	.....	.....	.....	585	.....	49	86	7
Apr.	51,410	48	.....	.....	8,174	.....	30,137	165	750
Total	323,348	75,088	15,188	2,119	118,034	5,274	404,255	3,444	228,384

As formal counting was not started until May 7, 1938, the summary lacks six days of representing a full year. The fish listed as trout are mainly sea-run steelheads. The category of "scrap fish" includes the following in the order of their abundance: sucker, squaw fish (Ptychocheilus oregonensis), chub (Mylocheilus caurinus and Acrocheilus alutaceus), and carp. There has been very little evidence of the movement of sturgeon at the dam. Only 44 were counted going upstream; 43 of these passed through the fish locks and one went up one of the ladders.

Continuous Passage of Fish

The daily count of fish varied tremendously. At the crest of the spring freshet of May 31, the count dropped to 15 salmon and trout. The opposite extreme of 20,322 of these species was reached on September 9. Such fluctuations in the number of fish were known to be a normal feature of the Columbia River salmon runs. A general knowledge of the grosser fluctuations in the runs was available from accumulated commercial fishery catch statistics, but this information was not sufficient to indicate the exact time or magnitude of the fluctuations, nor to form the basis of reliable estimates of the actual number of fish that should pass Bonneville at corresponding periods. It appeared that it should be possible to utilize commercial



Counting salmon through the fishways. Every fish that passes Bonneville Dam is recorded by observers stationed at the counting gates thus making possible a system of "bookkeeping" as an aid to intelligent management of this important resource.

catch statistics to observe individual fluctuations in the abundance of fish as they approached Bonneville. The presence or absence immediately thereafter of similar fluctuations in the counts of fish passing through the fishways then should indicate how readily the fish passed the dam and thus serve as a check on the efficiency of the fishways at the dam.

An opportunity to test this hypothesis occurred during the first week of counting. The commercial catch of chinook salmon in the 40-mile stretch of river between

Vancouver, Washington, and Bonneville showed a distinct peak on the night of May 9-10. The count of fish passing Bonneville reached a peak the following day. Graphs of the two sets of data show essentially the same trend toward the peak and toward the decline as the run dropped off again. Similar examples were observed later and in other species, all indicating that fish passed through the Bonneville fishways within one or two days after passing the commercial fishery 10 to 40 miles below the dam.

Passage of Fish Through Backwater Area

There has been a general tendency on the part of those who were not familiar with details of the project to anticipate that raising the water level at Bonneville would create a typical lake in which the velocity might not be sufficient to direct

Harvesting the silver horde in the lower reaches of the Columbia River. Here horses are often used in hauling the seine

the salmon in their upstream migration. The natural depth of the river between Bonneville and The Dalles was in many sections as much as 30 feet at low water. Raising the water surface by the construction of the Bonneville dam approximately doubles the sectional area in the pool at low flow. The velocity is therefore only reduced by about 50 percent, and still remains materially higher than at some places below the dam.

The fact that changes in the river above Bonneville did not disturb the passage

of fish through the pool was determined by a reverse of the procedure used to trace the fish through the fishways from below the dam. In this case, the fish counts were compared with the commercial catches at Celilo Falls, 50 miles above the dam. The peak of abundance of chinook salmon described above, appeared at Celilo two or three days after passing Bonneville.

A most convincing case for comparison was obtained in July, when the lowering of the water level above the dam for construction reasons impaired the operation of fishways for a period of five days. At this time the run of blueback salmon was at its peak; and while it is estimated that during these five days about 12,000 bluebacks reached the dam, only 4,343 passed through the fishways. This accumulation of fish then passed through during the next two days of normal operation, 8,407 being counted the first and 4,523 the second day. Nearly identical fluctuations were observed in the commercial catches at Celilo. A correspondingly abrupt drop occurred in the catch at Celilo two days after the interruption in passage at Bonneville; and after the resumption of normal passage at the dam, a corresponding increase appeared in the catch at Celilo during the succeeding second and third day. The trends of the runs of steelheads and chinooks on this occasion were not as distinct as in the case of the bluebacks, but it appears that they may have taken from five days to a week to reach Celilo. At no time was there any indication of extensive delay, and surely no failure of the fish to continue their migration.

Further evidence of the unhampered movement of the fish through the backwater area is found in the season's operations at the salmon egg-taking stations located on Wind River, Little White Salmon River, Spring Creek and Big White Salmon River, all of which are located along the backwater area. These stations collectively obtained about 42 million chinook salmon eggs, which is more than 10 percent above their average.

Fishway Operation

In designing the fishways for Bonneville Dam a great deal of attention was given to means of attracting the fish to the fishway entrances. It was believed that in the absence of an attraction greater than that provided by the simple flow from the ladders, the fish might become injured or seriously delayed while searching for a route of passage. There accordingly was developed a combination of features known as a "collecting system", which consists essentially of extensive auxiliary water supply and enlarged fishway entrances. In the collecting systems as installed at Bonneville, the flow through the ladders can be augmented about 20 fold, to give a total of at least 8,000 cubic feet of water per second to attract the fish to the fishways. As a matter of comparison, this is equal to a stream 800 feet wide and 10 feet deep, flowing at the rate of one foot per second.

The most elaborate collecting system is located at the powerhouse in the south channel of the river. The only flow in this channel is that which passes through the turbines and fishways. As very little power so far has been generated, few fish have been attracted into the south channel, and this collecting system, therefore, has not received a real test.

The collecting systems at each end of the spillway dam in the north channel have received a thorough trial. The dispatch with which the fish passed the dam is evidence of their success. Experiments conducted to determine the merit of the auxiliary water supply clearly demonstrated its advantage. At times of high river flow the fish seemed to follow closely along the shore lines, where they readily found the fish way entrances. Later in the season, when the peak of the run of chinook salmon coincided with reduced river flow, the fish spread more widely and a few were observed each day in the rough water immediately below the dam. It is believed that a few fish were fatally injured in this area, but the number was insignificant.

Each collecting system is designed to direct the fish to the dual fishways in the form of a fishladder and a pair of fish locks. The ladders were the first to be available for use, and their complete success immediately was demonstrated. The fish locks have been used only experimentally; but from the tests made, it appeared that the fish entered the ladders more readily than they did the locks. It was also found that a fish trap to prevent the fish from leaving the lock after having entered is a feature essential to their success. Traps were included in the design but were omitted in construction until their need had been demonstrated. Experiments with various types of traps are now in progress. In the course of the intermittent, experimental operation, over 10,000 salmon and trout have passed through the fish locks.

An additional fishway known as the Tanner Creek bypass, which receives water from above the dam at the extreme south shore and has its entrance at the mouth of Tanner Creek about 2500 feet below the power-house, was temporarily deferred; but work recently has been resumed on a schedule calling for completion in August of this year.

Passage of Downstream Migrants

Throughout the consideration of fish protection at Bonneville Dam, it has been recognized that the passage of downstream migrants presents more uncertainty than that of upstream migrants. This is due mainly to the difficulty of observing small fish in large bodies of water. Little was known of the habits of the small migrants or of the hazards to them of different water courses. It obviously was impracticable to screen a major part of the flow of the Columbia River with mesh small enough to prevent the passage of small fish and thus to divert the down-stream migrants away from routes that might be considered hazardous.

The program adopted for downstream migrants accordingly was one of providing as many definitely safe routes as practicable and attracting as many of the fish as possible to these routes.

The definitely safe routes that were provided include the three fishladders, five special bypasses, and the ice sluice at the powerhouse. Extensive laboratory and field tests seem to justify inclusion of the turbines among the safe routes, leaving the spillway as the only questionable route. Upon observing the turbulance of the water immediately below the spillway, one may justly become uneasy regarding the

safety of the little fish. This anxiety is relieved, however, when it is recalled that extensive runs of fish are required to pass through equally rough water at points such as Oregon City Falls, Celilo Falls, and Rock Island Dam.

If the downstream migrants are distributed evenly across the river, all but an insignificant portion of them surely pass through the spillway. On the other hand, if it is correct, as generally contended, that the little fish remain near the shore, a large portion should find their way to the bypasses. The bypasses themselves carry only a small volume of water, but they are accompanied by screened auxiliary water intakes, forming a combination that may be compared with the collecting systems for upstream migrants. A large volume of water flowing into the structure serves to attract the fish and to direct them to the bypasses.

The king takes to the air. Once in a while a Royal Chinook forgets that life had been made easy for him at Bonneville. Scores of photographers have been disappointed in their efforts to duplicate this pose in one of the fish ladders.

Photo by U. S. Department of the Interior.

Various observations have been made to determine the success of passage of fingerlings. The shore lines of the river below the dam have been observed at frequent intervals for evidence of injured fish that might be washed ashore, but none has been found. The men who count upstream migrants also record the number of fingerlings that pass downstream through their counting gates. A trap operated in one of the bypasses gives a record of the number of fish following that route, and trap nets have been used at several points to check the activity of the fish. Upon the basis of these findings, minor changes have been made in the structures to better direct the fish to the bypasses.

It was anticipated that there would be numerous adult steelheads migrating downstream after spawning. While it was recognized that a large proportion of these fish might pass through the spillway without being observed, it seemed that they would be evident at other points, such as in the ladders and the screened auxiliary water intakes. In the course of the year's observations, however, only six were seen. In the case of adult shad, a larger proportion was observed going downstream. Out of 5,274 counted on their way upstream, 40 were observed in the ladders on their way down again.

It is of interest to note that four hundred thousand scrap fish, including suckers, chubs, squaw fish, and carp were counted as they passed upstream through the ladders and that only 55 adults of these species have been observed on their way downstream.

Summary

Summarizing the year of experience with the fishways at Bonneville Dam, it is believed that a record has been established in the successful passage of upstream migrants by means of artificial facilities. Surely no runs of fish even approaching the magnitude of those at Bonneville ever before have passed through fishways. All classes of fish have passed without apparent delay. The writers know of no other instance in which major runs of fish pass through fishways without first accumulating below the obstruction to the extent that their presence is conspicuous.

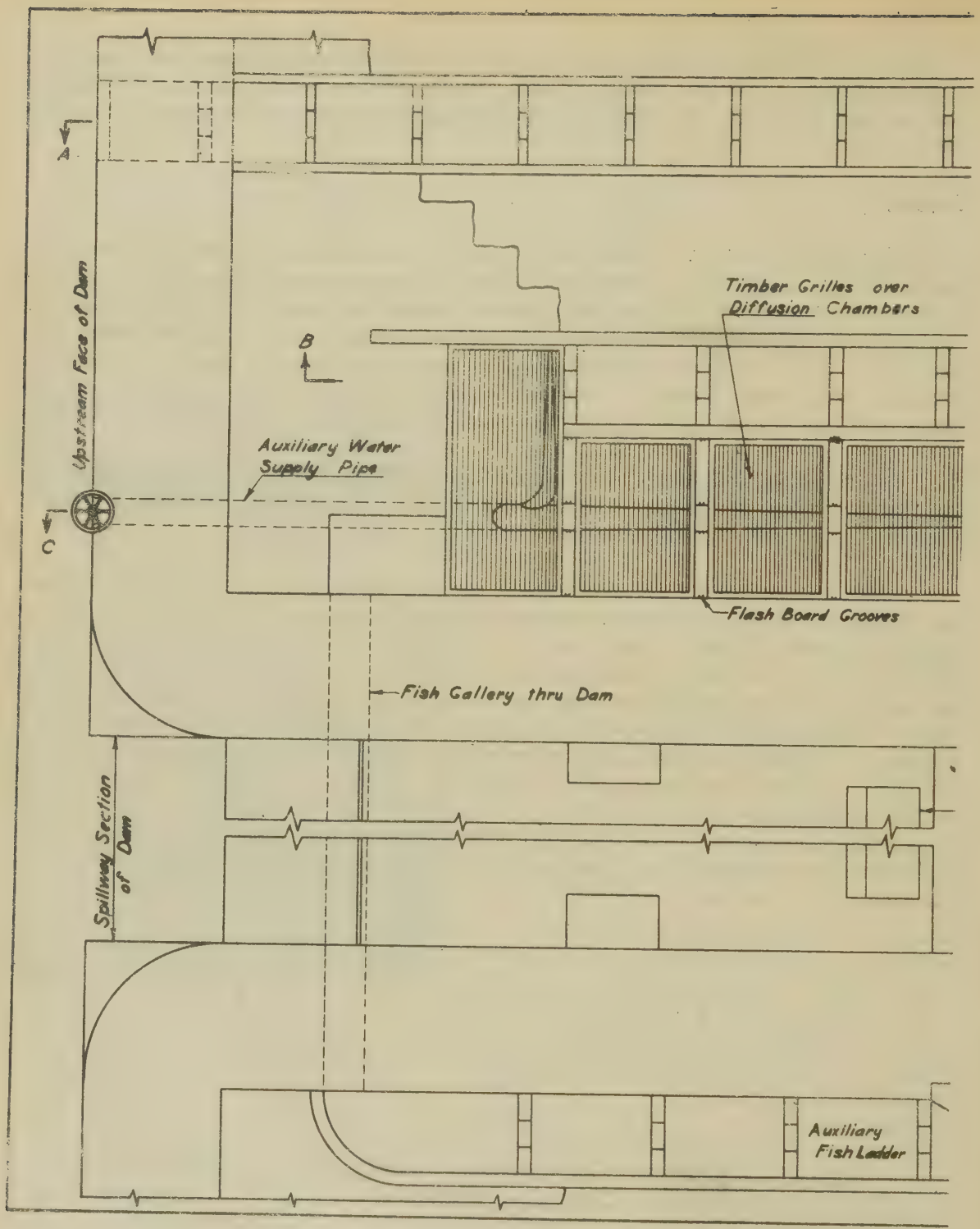
The situation relating to downstream migrants remains more of an uncertainty, due to the inability to make direct observations. There is no evidence, however, that the young fish are being injured.

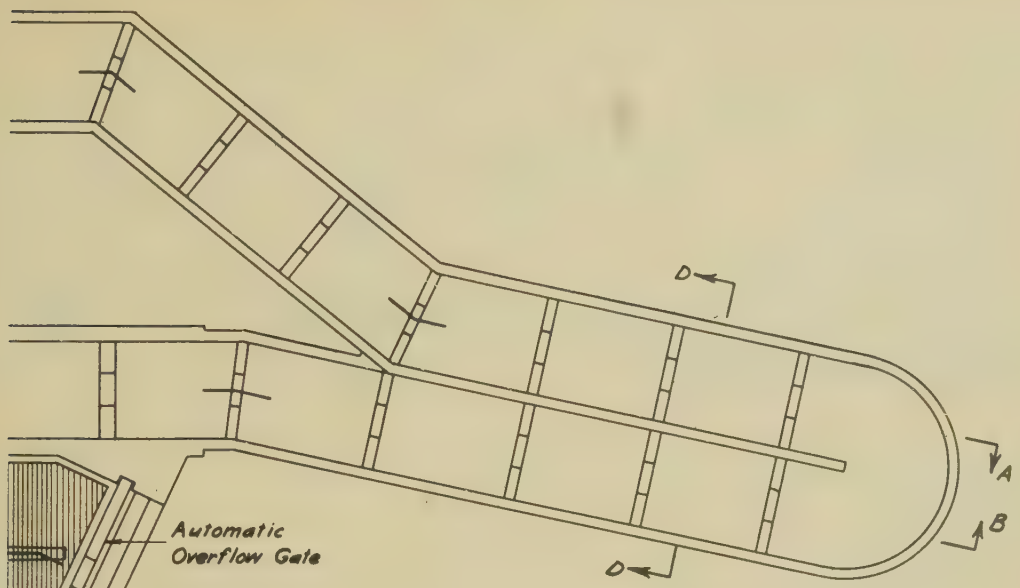
In conclusion, it is recognized that the success of the first year's experience can not be taken as evidence that the problem of fish migration at Bonneville is completely solved, leaving only routine operation of the fishways to follow. Conditions will be constantly changing. As more power is generated and a greater proportion of the flow is diverted from the north to the south channel, the fishways at the powerhouse, which have been little used as yet, must carry a large proportion of the fish. At the same time, the reduced flow through the spillway will present problems of attracting fish to the fishway entrances in the north channel. Such changes fortunately will be gradual, giving opportunity for adjustment to meet conditions as they arise. The Army Engineers, being fully aware of these problems, have spared no effort in the construction and operation of the fishways, and continuance of this policy is assured.

PLANS FOR CONSTRUCTING A SMALL FISH LADDER

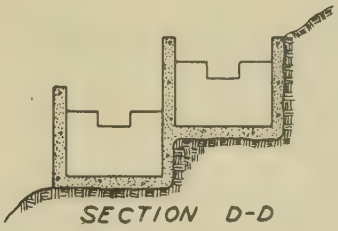
(Based on reports of O. W. Lindgren, Associate Hydraulic Engineer, Bureau of Fisheries)

THE ERECTION of dams without suitable fishways in streams used by migratory fishes to gain access to their spawning grounds has been one of the major causes of the decline of the salmon fisheries in the northwestern states. Impassable dams undoubtedly played an important part as well in the virtual extinction of the Atlantic salmon many years ago, and in the decline of the Atlantic coast shad fisheries. Other


A
Upstream Face of Dam
Timber Grilles over Diffusion Chambers
B
Auxiliary Water Supply Pipe
C
Flash Board Grooves
Fish Gallery thru Dam
Spillway Section of Dam
Auxiliary Fish Ladder



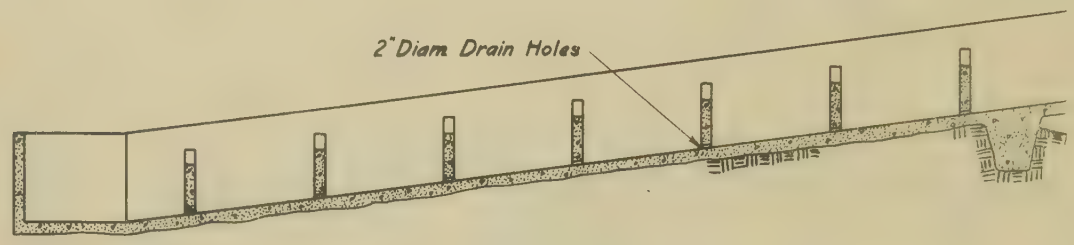
Spillway
Bucket



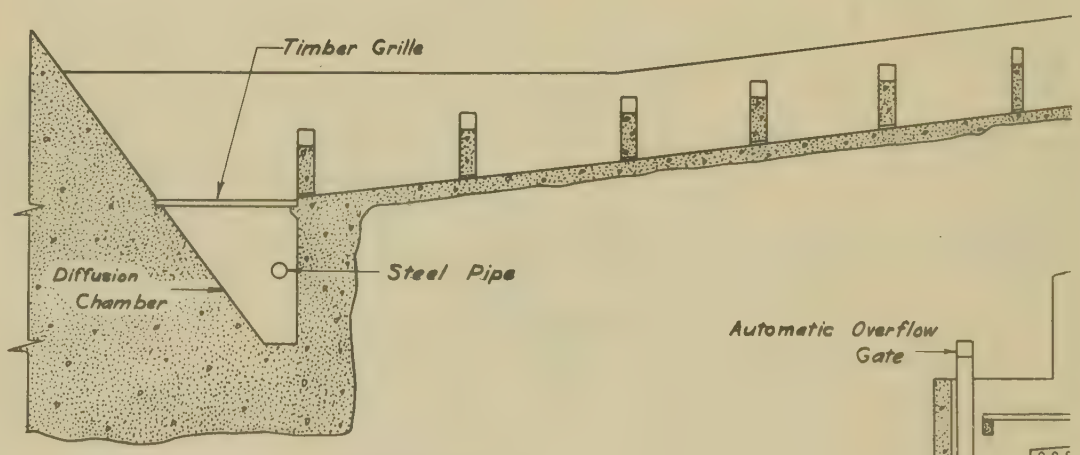
SECTION D-D
Showing Weirs

DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
SEATTLE OFFICE
PLAN OF TYPICAL
FISH LADDER

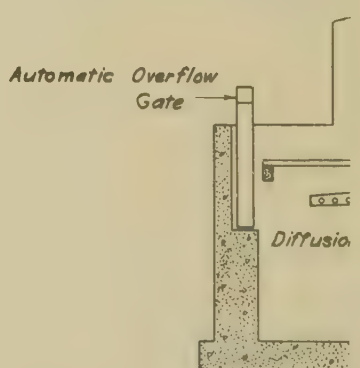
Drawn By: D.S.	Date: May 1, 1934
Checked By:	Plan No.:
Approved By:	Sheet No.: 1 of 2

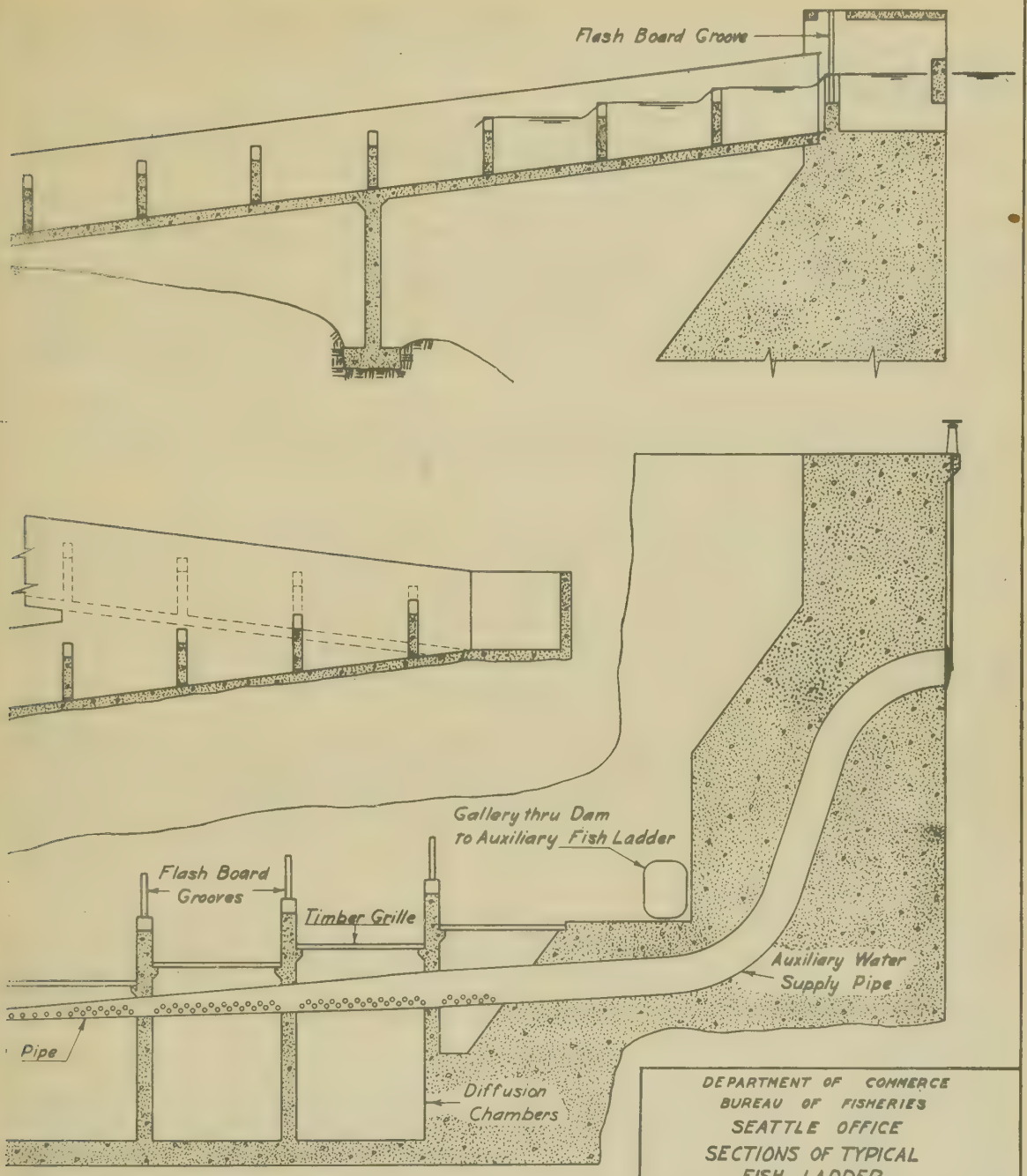


SECTION A-A



SECTION B-B





SECTION C-C

DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
SEATTLE OFFICE
SECTIONS OF TYPICAL
FISH LADDER

Drawn By: D.S.	Date: May 2, 1934
Checked By:	Plan No.:
Approved By:	Sheet No.: 2 of 2

kinds of fishes have been affected to varying degrees, depending largely on the strength of their migratory instinct and on the extent of the spawning areas cut off from access by the dams.

The need of fishways is most apparent in streams visited by the so-called anadromous fishes like the salmon, steelhead trout, and shad, which annually enter fresh water from the ocean for the purpose of spawning. However, many other fishes which spend their entire lives in fresh water show a marked tendency to ascend toward the headwaters at spawning time. To these species also the construction of proper fishways may be highly important. At Bonneville Dam on the Columbia River a great variety of river fishes has been observed in the fish ladders. Among these fresh water species were carp, suckers, squaw-fish, whitefish, trout, bass, and catfish.

Because of the large number of requests which are received by the Bureau of Fisheries for information regarding the construction of small fish ladders, the accompanying plans and instructions have been prepared.

It should be borne in mind that every project may present a different problem, depending upon the species of fish encountered, and that no standard rules can be given which will apply to all conditions. The characteristics and habits of the fish must be thoroughly studied before the details of the structure are worked out. The type of structure described in this report is most readily adaptible to migratory salmon, such as are found in the Pacific Coast rivers.

The common type of fish ladder is a simple inclined trough or flume used for passage of fish over a dam. In the trough, spaced at intervals, commensurate with its size, are cross walls known either as baffles or weirs. These cross walls serve as checks to retard the flow of water and form a series of pools that may be likened to a water stairway up which fish may travel. Access from one pool to the next is gained by the fish passing through openings in the cross walls or by jumping over the wall when it serves as a weir. The ladder structure is generally built of concrete, but for minor structures wooden construction is quite satisfactory. The character of the entrance to the ladder, the size of the pools, the height between successive pools and regulation of flow of water down the ladder are important features in its design.

Entrance: Primary consideration must be given to the design of the approach channel and entrance to the ladder. The fish should be attracted to it by simulating, as nearly as possible, the natural conditions of stream flow. This is accomplished by maintaining an adequate supply of water flowing through an approach channel leading from the main channel of the stream to the ladder entrance. This may be termed a collecting channel and its purpose should be to attract fish away from the tailwater at the base of the dam and direct them into the ladder. Artificial means for producing a modified turbulent condition at the ladder entrance is very effective. A practical method for creating this condition is to add water in the lowest pool of the ladder. For this purpose auxiliary water is supplied through a pipe which discharges into a bottom chamber, from whence it rises through floor grilles that serve to diffuse and aerate the water in a manner which attracts fish.

The more active species of fish, such as migratory salmon, are capable of swimming against velocities of 10 feet per second but for purposes of design the maximum velocity in the approach channel should be limited to about five feet per second. If more sluggist types of fish are handled the limiting velocity may be even less.

The placement of the entrance is perhaps the crucial element in the success of any ladder. Migratory fish will readily ascend most of the ladders now in use in the Pacific Coast region, but many otherwise well designed ladders are only partially effective because the fish fail to find the entrance readily. Every installation presents a different problem in design and great ingenuity must be displayed in meeting the requirements of the fish.

Ladder Pools: Once the fish enter the ladder, the problem is to keep them moving upstream through a series of pools that constitute the water stairway. The dimensions of the ladder are governed by its requirements, depending upon the quantity of water and number of fish to be handled. The recommended rise or difference in elevation between pools is one foot and should never exceed two feet. The more active species of fish, such as trout and salmon, can easily negotiate a jump of from one to two feet high providing there is an ample flow over the weir. The usual practice is to make a notch about one foot wide by six inches deep in the crest of the weir to give a good depth of overflow through which the fish will jump. For fish that are not accustomed to jumping a means of passage, such as a hole through the weir wall or an opening around its end, must be provided. The velocity of water flowing through the pools should be swift enough to keep the fish active and stimulate them into moving steadily upstream. Recommended velocities through the pools may range from 2 to 5 feet per second. Velocities in excess of this will necessitate too great an exertion and may result in injury to the fish in their attempt to fight their way upstream.

Outlet: The ladder outlet should be located at the level of the reservoir above the dam. The customary outlet is constructed as a sump with stop logs or gates for regulating the flow of water and permitting fish to find exit into the reservoir. In reservoirs which are subject to a great variation in level, the outlet works must be adapted to meet the condition, keeping in mind that a flexible control of water must be maintained for any stage encountered. Care should be taken to prevent contaminated water from entering the ladder as experience tends to show that some fish are quite sensitive to contamination and may shun the latter if such conditions are found.

F I S H S C R E E N I N I R R I G A T I O N D I V E R S I O N S

(Based on reports from O. W. Lindgren, Associate Hydraulic Engineer, and John Spencer, formerly temporary Engineer, U. S. Bureau of Fisheries)

ONE OF THE MOST serious dangers threatening young salmon on their seaward migration is the possibility that they may enter one of the numerous irrigation diversions from the main stream. When this happens, they seldom, if ever, find their way back to the river but work into the smaller laterals of the irrigation system and eventually are stranded on dry land.

With the development of agriculture and the increase in the amount of land requiring irrigation, most of the major streams in the northwestern states have been tapped for irrigation purposes. In the past many of these streams and their tributaries supported excellent runs of salmon and steelhead trout, but in many cases only fragments of the former runs remain.

Although it has long been recognized that enormous losses of fish life occur annually in unscreened irrigation diversions, no comprehensive counts or surveys have been made with a view to measuring this loss in actual figures. Such incomplete censuses as have been taken, together with the opinions of fishery authorities familiar with local conditions, support the view that the development of irrigation projects without proper means of fish protection has been an important element in the decline of salmon resources in northwestern United States.

In 1920, after a survey to determine the loss of fish in irrigation ditches supplied by the Yakima River, an investigator of the Bureau of Fisheries reported the finding of 4,000 fish, of which 90 percent were migrating salmon, in a 200 acre tract. For the 250,000 acres then under irrigation, this would indicate a loss of approximately 5,000,000 fish at one watering, 4,500,000 being salmon in their first and second years. For an entire season this figure would have to be multiplied many times.

The following isolated observations give a further indication of the magnitude of fish loss in irrigation diversions. In 1929 a check on an unscreened ditch which diverts water from a tributary of the Yakima River revealed a total of 5,900 salmon and steelhead 3 to 8 inches long. In June, 1930, a school of young salmon estimated as numbering 10,000 fish appeared in the Sunnyside Canal at a point 60 miles from the entrance. In the same year an observer counted 1,600 salmon in the Wapato system and estimated that an additional 17,000 salmon and 450 steelhead trout were scattered throughout the system.

Protection of Fish at Irrigation Works

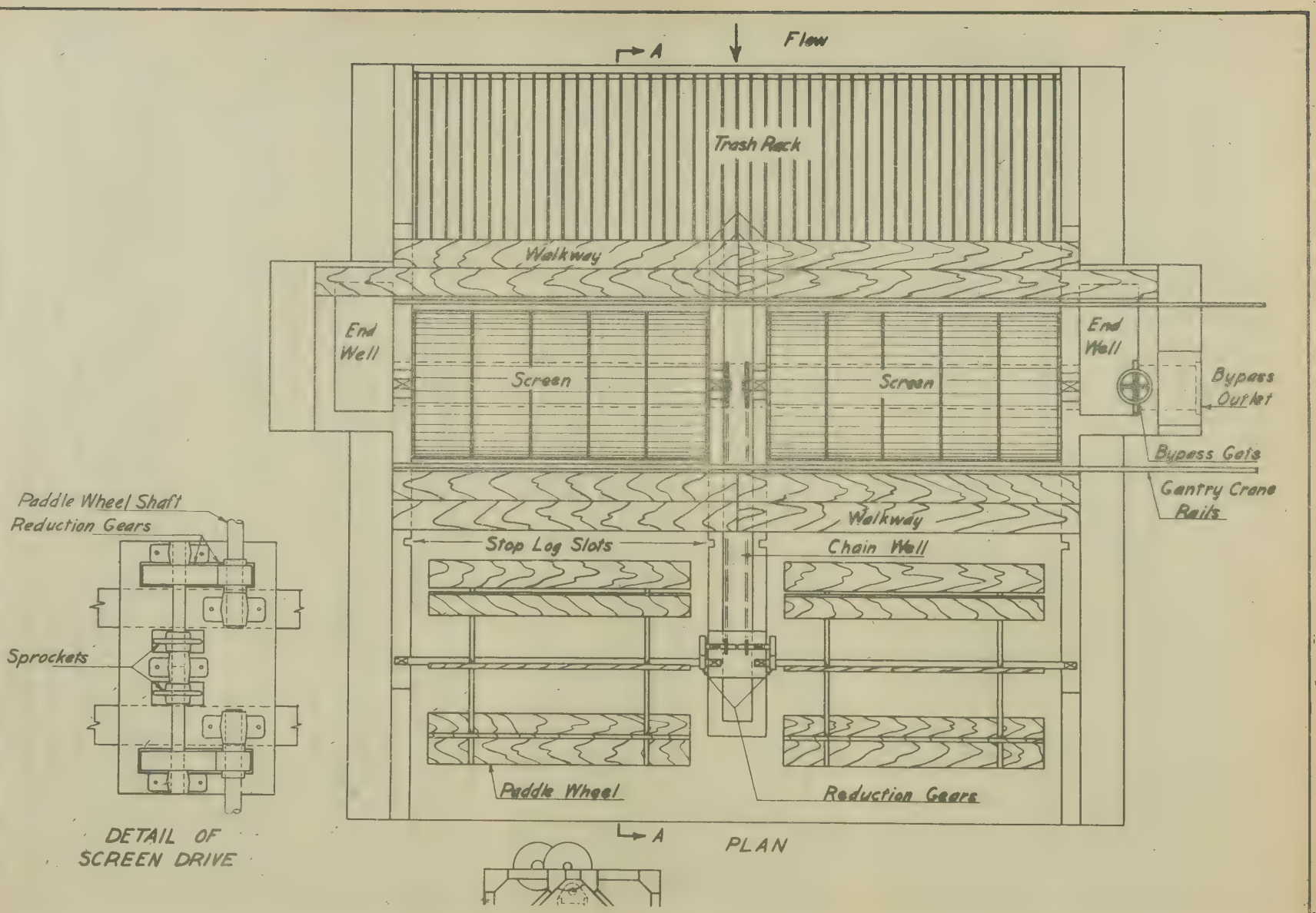
The destruction of fish in water diversions may be prevented by properly designed and constructed fish-protective devices commonly known as fish screens. These screens are barriers placed at or near the intake of water diversions to prevent the entrance of fish without interrupting or interfering with the flow of diverted water or its use.

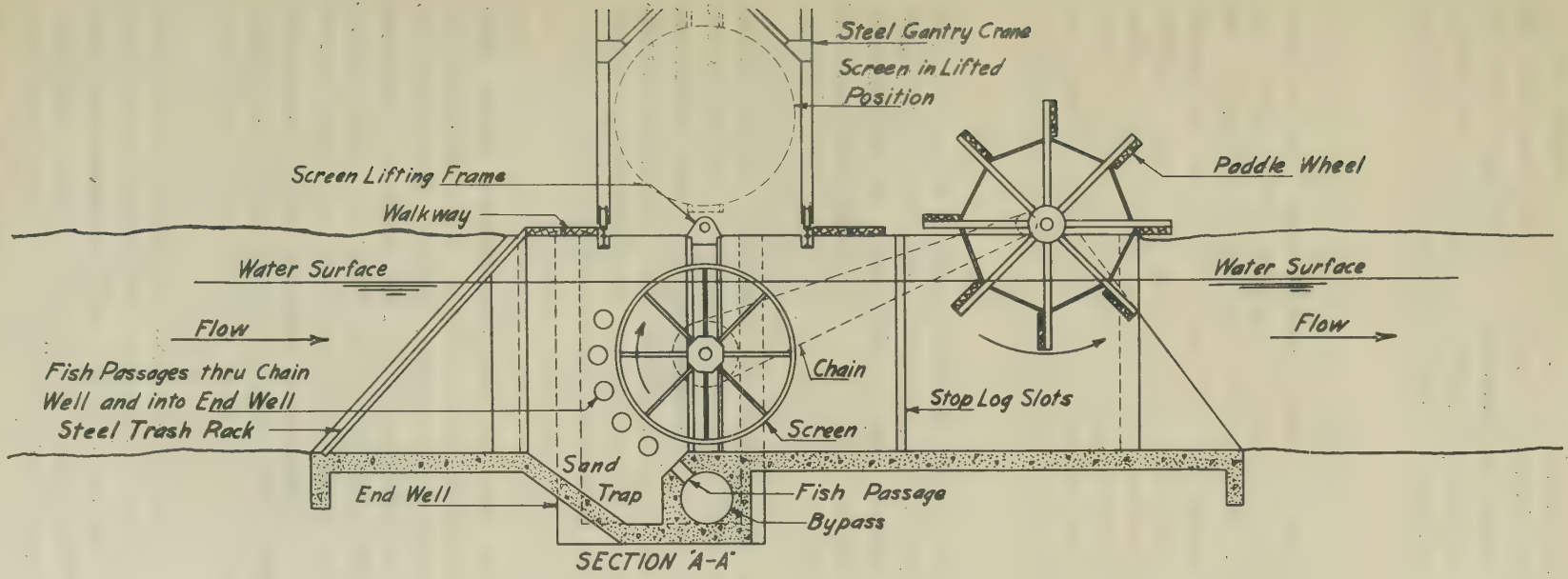
The experience of the Bureau of Fisheries in devising or installing fish screens has been limited to the Pacific northwest, where the Bureau has been engaged in supervising the screening of a number of large government-owned irrigation diversions. Although the results of this experience may not be applicable in all details to screening problems in other localities, the following descriptions of commonly used screens are provided for the information of interested persons. Modifications may be introduced as local conditions demand.

Rotary Screens: The most effective fish screens used by the Bureau of Fisheries are the revolving drum type as shown in the accompanying drawing. This type is used to prevent small migratory fish from being diverted from the rivers into the irrigation or power canals. The screens are placed in the canal as close to the headgates as possible in order that the least number of fish may be left stranded when the canal is shut down. A by-pass, leaving the canal at a point just above the screens, serves to carry the fish back to the river. The small migratory fish will not swim upstream, consequently they become stranded in front of the screens if the by-pass is not provided. The velocity of the water through the screens is about 1½ feet per second which is attained by widening the canal sufficiently to obtain the desired velocity. A fairly long transition is used on the upstream side in order that the velocities will be uniform through the screens. A shorter transition is used on the downstream side.

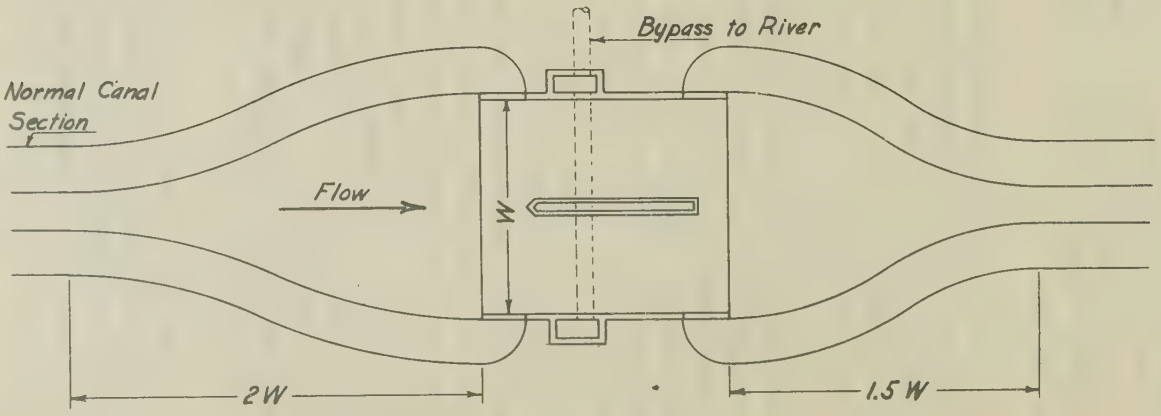
The diamater of the screen drum is determined by the depth of the water flowing in the canal. Screens up to 5 feet in diameter have about 9 inches freeboard. Larger screens have from 12 inches to 18 inches freeboard. The length of the screen drum is dependent on the amount of water flowing in the canal. The drum frame is built of structural steel and is covered with No. 3 mesh 12 gauge galvanized wire screen. Rubber strips fastened to the side walls and floor bear against the ends and bottom of the screen drum, thus forming an effective seal to prevent the fish from escaping through the clearance spaces. The screen drums are mounted in frames which rest in guides in the structure. No bolts or clamps are used to hold the frames in place. A traveling gantry crane is provided so that the screens may be removed quickly and easily.

Each screen is driven by a separate paddle wheel, so that if one screen is stalled, the others will continue to turn. The power is transmitted from the paddle wheel to the screen by means of a pair of reduction gears and a chain. The chain is lubricated by an oil film which rests on the surface of the still water in the chain well. The peripheral speed of the screen is about 5 feet per minute, while that of the paddle wheel is about half the velocity of the water.


A
Flow
Trash Rack
Walkway
End Wall
Screen
Screen
End Wall
Bypass Outlet
Bypass Gate
Gantry Crane Rails
Walkway
Stop Log Slots
Chain Wall
Paddle Wheel
Reduction Gears
A
PLAN
Paddle Wheel Shaft
Reduction Gears
Sprockets
DETAIL OF SCREEN DRIVE



SECTION 'A-A'



PLAN SHOWING TRANSITIONS

DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
SEATTLE OFFICE

TYPICAL FISH SCREEN INSTALLATION

Drawn By: D.S.	Date: March 28, 1939
Checked By:	Plan No.:
Approved By:	Sheet No.: 1 of 1

The by-pass runs the entire width of the structure directly beneath the screens, and fish passages enter the by-pass just in front of the bottom seal. At each end of the by-pass are wells which facilitate the cleaning of the by-pass when the canal is drained. Fish passages are also placed through the chain well and through the walls into the end wells so that the fish may find their way into the by-pass. A gate in the outlet end well is used to control the amount of water diverted through the by-pass.

A sand trap is formed in the floor of the structure in front of the by-pass. It collects the silt which might otherwise get into the by-pass through the fish passages. A trash rack in front of the screens protects them from logs and large debris. Since the screens rotate against the flow of water, the small debris, leaves, and moss that go through the trash rack, are carried over the top of the screen and washed free on the down stream side. A gantry crane which operates on top of the structure is used for handling screens. Crane rails extend off the structure and onto a platform on one side which serves as a repair platform. Walkways beside the gantry rails facilitate the handling of the crane and the screens. The trash rack is raked from the upstream walkway. The trash rack sections may be removed by means of a swinging boom on the gantry crane.

Stop log slots are provided between the screens and the paddle wheels. The stop logs are used to make the velocities uniform in a multi-unit installation. They also serve to hold the water level up if the quantity drops below normal. If the quantity is insufficient to drive all the paddle wheels, some of the units may be blocked off completely with stop logs, thus diverting all the water through the other screens.

One example of a large installation completed in the spring of 1939 is on the Wapato Canal near Yakima, Washington. This canal has a normal flow of 1300 second feet. Ten screens and paddle wheels are used, each screen being 13 feet in diameter and 12 feet long. The cost of this complete installation is about $62,000. Usually, a screen installation will cost about $50.00 per second foot of water handled. If power is available at the screen site, a motor drive is sometimes used.

Parallel Bar Screens: In some cases the revolving type screens are not applicable, such as for a tunnel outlet of a reservoir. In these special cases, stationary screens are used. Such screens surround the tunnel entrance and are of the steel grating type usually built in small removable panels. Each panel rests in guides so that it may be removed easily and quickly. The disadvantage of this type of screen is that it becomes clogged with moss and weeds and requires frequent cleaning. Furthermore, the narrower the spacing between the bars the more trouble from clogging is experienced, consequently it is not practical to screen out the very small fish with the steel grating type of screen. Their only practical use is where partial screening is considered satisfactory.

Parallel bar screens are generally of flat steel, spaced one-half inch or less apart, though spacing is dependent on the size of fish to be stopped. The front face should be free from projections so no interference will be encountered when cleaning. In using the ordinary or rectangular steel bars it is found that small pieces of debris will start through the spaces and then, because of the irregulari-

ties, will become lodged between the bars. The removal of this lodged material may be tedious. To obviate this condition the use of a deformed bar is suggested. For ordinary purposes a bar 3/8" x 1" x 3/16" may be used, the front face being the 3/8" dimension. Any material passing the smallest space between the bars will not lodge but will be carried through by the flow of the water. This is a stock steel bar and its cost is only slightly in excess of the regular rectangular steel shape.

BLUEGILLS FROM MARYLAND MAKE GOOD IN SOUTH AFRICA

By A. Cecil Harrison, Inland Fisheries Advisory Officer,
Cape Provincial Administration, Cape Town, South Africa

FOLLOWING HIS SUCCESS in sending the smallmouth bass to South Africa, of which I wrote in No. 42 of the PROGRESSIVE FISH CULTURIST, Mr. A. M. Powell, Superintendent of Hatcheries, Maryland Conservation Department, determined to give us the bluegill sunfish we wanted.

Largemouth bass have made great progress in our few natural lakes and in the larger irrigation reservoirs since 1930; in fact this fish has been spread all over the country and now provides good fishing in many districts where the people had never seen a fish worth catching and eating. The multiplication of minor storage works and state-aided farm dams has been phenominal during the last few years, and as soon as there is water available the people want largemouth bass. But many of these waters are too small to support a profitable stock of bass; and after the first season of apparently assured success, the owner realizes that his acreage can produce only a certain poundage of this voracious fish, which usually means a few big cannibals. In the remote country districts, where fresh sea fish is almost unknown, his table would be better served by a consistent supply of small succulent panfish. We had no suitable panfish to distribute in response to this ever growing demand. Our native fishes which will breed in small enclosed waters are almost worthless for the table. Carp are taboo as they roll and foul the water and their flesh is not liked; tench are not much better and we plant them mainly as breeders of forage for bass in weedy waters, and the European perch is an uncertain breeder. So we decided to try to acclimatize the bluegill to fill the role of household panfish for the farmers, and also to plant along with the largemouth bass in fishing waters to provide minor sport with the fly-rod.

The first attempt was made by the m. v. CITY OF NEW YORK during June 1938, and four of the cypress shipping tanks and the aerating equipment described by Mr. Powell in No. 33 of the PROGRESSIVE FISH CULTURIST were used. We know that he did everything

possible to carry out his plans, but there was an unannounced delay in the saiing of the vessel coupled with bad freight loading trouble, so that he had no chance of getting the tanks aboard on the day they were trucked to New York. Then there was another lapse of time between the sailing and the starting of the air pumps and taking it all round that voyage started very badly for the fish. In fact a number of the bluegills died at New York docks and the mortality was heaviest during the early days of the trip. Finally, only 4 bluegills out of 40 reached Cape Town on June 24. These survivors were in quite good condition, although starved on the voyage, and were about 4 inches long, being stock bred in May 1937 by Mr. Fred Tresselt, Thurmont, Md. We took them to the Jonkershoek Hatchery and put them in a small quarantine furrow in a foot of water running gently over a gravel bed. June water is warming in the States but chilling in our Cape climate, the seasons being reversed in the opposite hemispheres. The water at the Jonkershoek Hatchery rarely gets colder than 50 degrees Fahrenheit all winter, but it remains too cold for the breeding of bass until

Aboard the M. V. "City of New York" at Cape Town docks, June, 1938, showing earlier type of shipping tanks used for smallmouth bass and bluegills on the fore-hatch cover

early October when our spring is well on the way. On July 22, the plumpest of the 4 bluegills was found dead with all the scales rubbed off the abdominal region. When a slight incision was made at the vent, a stream of eggs gushed out. It must have been ripening when it left the States and had then spent two warm weeks in the tropics. Had we only known it, a warmed tank might have done the trick as the other three bluegills were males. June is evidently a hazardous time to ship maturing bluegills to a temporarily colder climate. The three males survived and had grown to about 8 inches long by March 1939.

We asked Mr. Powell if he would try again, and found him undaunted by the misfortune of June and more determined than ever to complete the job; with the result that he prepared a new set of improved shipping equipment to carry a larger number of bluegills on the October 1938 voyage of the m. v. CITY OF NEW YORK.

Six cypress tanks 2' 6" x 2' 6" x 2' high were used. An air compressor of standard make of 1-1/2 cu. ft. per min. capacity, with filter and automatic regulator, driven by a 1/4 H. P. motor from the ship's 110 v. D. C. supply, was housed in a wooden casing. Air line, distributor and connections to basswood diffuser blocks fastened to the floor of each tank were provided. As on previous voyages, the shipping tanks had to be placed on the fore-hatch cover with the aerating plant and motor connections sheltered under the forecastle. Mr. Powell brought everything from Lewistown, Md. to New York, and as the ship's sailing was again delayed for a day, he stopped over in New York and arranged that the air be kept going in a garage until it was time to put the tanks aboard. He saw everything properly set up on the ship and in running order before he left. 20 small bluegills, 1" to 1-1/2" long, hatched during May 1938, were put into each of the six tanks, and as before no feeding was done on the voyage. Mr. A. M. Vida, Chief Wireless Operator, again took charge of the fish, and his daily noon readings of the water temperature in the tanks were as follows:-

Date October:	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Degrees Fahr.	67	58	64	74	76	76	78	78	78	78	78	78	78	76	74	71
Date October:	18	19	20	21	22	23	24	at Cape Town								
Degrees Fahr.	68	64	62	64	64	62	64	(= new hatchery water)								

The water temperature in all six tanks was uniform throughout. This range was similar to that on the voyage of October 1937 with smallmouth bass, with the important exception that the peak was consistent at 78 degrees Fahrenheit, and did not shoot up to 83 degrees Fahrenheit as in 1937.

Heavy seas were encountered off the American coast during the first 4 days of the voyage, and tanks Nos. 1 and 2 were contaminated. But the fish in these tanks did not begin to die off until October 7 when the temperature was rising and loss was heaviest on October 10. There had been no loss in the other tanks, and as soon as Mr. Vida discovered the cause of the trouble by tasting the saltiness of the water, he removed the survivors from these tanks and distributed them in the others. Samples from the affected tanks tested at Cape Town showed the water to contain 6.24 gms. of Sodium Choride per 1,000 cc., compared with about 35 gms. of salts per 1,000 cc. in normal sea water. After October 10, the mortality rate was low and was confined to tanks Nos. 3 and 6 which were afterwards found to contain a slighter trace of salt.

When the vessel docked at Cape Town there were 72 bluegills alive out of the 120. The Maryland water was clear and the pH about neutral, but there was a great

deal of slime and whitish sediment in the tanks. All the fish were thin and weak and had suffered very badly from fin and tail erosion. We removed them all into a perforated can of their tank water, and then they were given a slow trickle of the new hatchery water (of which we had brought a truck load of cans) and this was continued for about half an hour. Meanwhile, three of the shipping tanks were emptied and scrubbed clean, diffuser blocks were cleared and new rubber connections made, and these tanks were refilled with the new hatchery water. Twelve of the fitter bluegills were sorted out into each tank and the air turned on. As the bluegills were so starved and weak, food seemed essential if any were to survive the extra 7 days voyage to Durban, Natal, so we put in a good supply of lively bloodworms (chironomid midge larvae) which would live in the water until eaten. The Natal Provincial Administration received 27 of these bluegills alive at Durban, and Mr. Vida reported that their condition was better there than it had been at Cape Town.

The author putting bluegills into the "quarantine furrow" at the Jonkershoek Hatchery, Stellenbosch, Cape Province, South Africa, June, 1938.

The half share of this shipment of bluegills assigned to the Cape Province was taken to the Jonkershoek Hatchery and placed in the usual isolation furrow. Four died during the first week. The 32 survivors were sorry looking specimens and swam very awkwardly as their fins and tails were reduced almost to stumps; but they regained condition very quickly, the fin rays were perfectly regenerated, and no more fish were lost. We kept them in the small furrow for over two months as we did not expect them to breed that summer, for they were only little 5 months old fingerlings

when they came to us. By the end of 1938 they were 2 1/2" long and in great fettle, so we turned them out into a vacant pond of .11 acre to grow out, so we thought, in time to breed next spring. This has always been a fine growing-pond and we have used it in the past for European perch, and last year for growing out the imported small-mouth bass from Maryland. In its unoccupied state last midsummer it was just teeming with small live food and the tadpoles of the clawed frog (Xenopus laevis) which are plankton feeders and good forage for bass and similar fish. We put in the bluegills on December 29, 1938, and in three weeks time many of them had grown to 4" long, had assumed their depth of body and become brightly colored. On January 24, a four-inch male was found guarding a bed of eggs. This was at the height of the hot, dry season, and the water temperature reached 80 degrees Fahr. after noon. The eggs hatched on January 27, and on February 3 the fry were swimming and feeding. Several other males had later nests in which more than one female spawned and good shoals of fry resulted. By the end of March 1939 we had many young bluegills 1-1/2" to 2" long, and bigger than their parents had been when they arrived in October 1938.

Close-up of a historic moment. The first bluegill takes the water in South Africa, June 1938

Thus we will be able to commence the distribution of this new stock in the coming months, when the cool weather allows their transport to distant parts by rail. We were glad to learn that the bluegills of the October 1938 shipment sent on the Natal also matured and bred at about the same time as ours.

In connection with the difficulty of distributing fish during the South African summer, when unattended shipments of bass cannot be sent by rail, we got over this in

the case of the new valuable brood of smallmouth bass (hatched at the Jonkershoek Hatchery in October 1938 from Mr. Powell's Maryland stock) by using air transport. Four consignments of young smallmouth bass were sent by the South African Airways service from Cape Town to Durban, Natal, during last December and January at the hottest period, using shallow 5-gallon cans packed in wicker baskets. A total of 206 small mouth sent that way all arrived in excellent condition, enabling Natal to get months ahead with their program of growing out the fish during summer, instead of having to wait to have stunted fish sent them on a 3 day rail journey in winter. The fish left the Cape Town airport at 8:30 A.M., arrived at Durban at 3:30 P. M., and were then taken inland by road to Howick and were in their new ponds by the evening of the same day. On January 10, we sent a can of 25 smallmouth fingerlings by air to Germiston, the airport for Johannesburg, Transvaal, where they were collected and taken 250 miles by road to Mbabane in Swaziland, arriving at 9:30 P. M. that day, a journey of over eleven hundred miles and all arrived in good order. On March 4, we sent 48 smallmouth by air at 6:30 A. M., and they reached East London on the Indian Ocean coast at 11:30 A. M. There some enthusiasts from the Transkeian Native Territories were ready to motor them to reach their new homes before nightfall, to establish local breeding ponds from wnich some of the fine Transkeian rivers may be stocked.

N O T E S O N T H E E F F E C T O F L O W T E M P E R A T U R E U P O N E Y E D E G G S

By Frederic F. Fish
Associate Aquatic Biologist, U. S. Bureau of Fisheries
and Roger E. Burrows
Apprentice Fish Culturist, U. S. Bureau of Fisheries

THE QUESTION has sometimes been raised whether or not any permanent injury may be inflicted upon fish eggs through their subjection to the relatively low temperatures prevailing in egg cases during shipment. This question may be argued in either direction purely upon the basis of indirect evidence which can be summoned in support of either contention. In so far as is known, this question has not been investigated, hence preliminary experiments in this direction were undertaken at the Quilcene Experimental Laboratory.

Small, experimental egg shipping cases, measuring approximately 36" x 36" x 18", were constructed which contained a single stack of five egg trays, two moss trays, and the usual space for ice. These cases were designed as small scale duplicates of

the usual type of egg shipping case with the air, ice, and egg spaces as closely proportional to those in the standard egg case as was possible to estimate them.

On November 22, 1938, 30,000 eyed chum salmon eggs which had all been spawned on the same day were thoroughly mixed in a large egg basket and subsequently divided by the usual volumetric technique into eight lots of 3,650 eggs each. Seven of the eight lots were then "iced down" in individual experimental egg cases, the eighth lot being placed immediately on an egg tray in an experimental trough to serve as an uniced control. The experimental troughs at the Quilcene Experimental Laboratory measure 48" x 14" x 8", inside dimensions, and are supplied with approximately six gallons of water per minute. During the period of experimentation, the water temperature ranged between 39° F. and 42° F.

At two day intervals thereafter, an experimental egg case was unpacked and the eggs, after tempering, placed on an egg tray in an individual trough for incubation. Thus, a graduated series of exposures ranging from 0 to 14 days by two-day intervals was obtained.

EFFECT OF LOW TEMPERATURES UPON SUBSEQUENT LOSSES

The losses apparent upon unpacking each egg case and those occurring daily thereafter were recorded up to the time the experiment was terminated on March 21, 1939. By that date, the fish had reached the 1-1/2 fingerling stage. As there is little to be gained by listing the losses by days herein, they have been grouped according to the development stages of the fish in table #1.

From the standpoint of losses, there seems to have been no injurious effect exerted upon the eggs through their exposure to the low temperatures for as long a period as two weeks.

TABLE I. L O S S E S

	Trough Number							
	17	18	19	20	21	22	23	24
Days Iced	0	2	4	6	8	10	12	14
Loss in egg case		4	1	260a	4	14	16	15
Loss during egg stage	125	80	48	288	92	105	64	103
Loss during fry-fingerling stages	500	348	2182b	122	234	501	2162b	160
Total Losses 11/22 to 3/21	625	432	2231	670	330	620	2242	278

a- The relatively large loss found upon unpacking the six-day lot was apparently caused by the toxic action of some soluble substance in the wood used in constructing two of the egg trays. The loss was confined to these two trays, the scrim of which was stained a deep brown when the case was unpacked. There was no evidence to believe that this loss was in any way connected with the exposure to low temperature.

b- The large losses attending the sac-fry stage in this lot were caused by an abnormal absorption of the yolk material. The yolk sac became constricted at the distal end and usually ruptured causing the immediate death of the affected fry. Why this condition should be present in only two lots of eight is conjectural. It was, however, probably not caused by exposure to the low temperature.

TABLE 2. THE RATE OF HATCHING EXPRESSED IN DAYS SUBSEQUENT TO NOVEMBER 22

	Trough Number							
	17	18	19	20	21	22	23	24
Days iced	0	2	4	6	8	10	12	14
First egg hatched	23	23	24	23	24	25	28	23
10th percentile	27	29	30	30	31	32	34	35
50th percentile	30	32	32	33	33	34	36	37
90th percentile	32	34	34	35	36	37	39	40
Last egg hatched	42	43	42	42	43	46	54	54

EFFECT OF LOW TEMPERATURE UPON THE RATE AND DURATION OF HATCHING

As might be anticipated, icing the eggs did prolong their subsequent incubation period. The low temperatures prevailing in the experimental egg cases did not, however, completely interrupt the development of the eggs for the delay in hatching of each lot failed to equal the period of exposure for that lot. The various percentiles of the fry present in the individual troughs on successive days during the hatching period have been used as indices of the hatching rate. The results, expressed in the number of days subsequent to the start of the experiment, are given in table #2.

The 50th percentile (i.e., the point at which 50% of the eggs have hatched) is used to indicate the effect on egg development in each lot by the exposure to low temperatures. A 2, 4, 6, 8, 10, 12 and 14 day period under iced conditions produced only a 2, 2, 3, 3, 4, 6, and 7 day lag in hatching respectively. As may also be seen in table #2, an icing period in excess of eight days prolonged the duration of the hatching period as measured by the extremes of the first and last egg hatched. It did not, however, affect the spread of the hatching period measured by the 10th and 90th percentiles as this remained practically constant in all lots.

EFFECT OF LOW TEMPERATURE UPON SUBSEQUENT GROWTH

In view of the delay in hatching produced by exposure to low temperatures, it was conceivable that the fish resulting from eggs iced for the longer periods might in some manner be handicapped in their subsequent rate of growth so that, even under favorable conditions, they would never overtake the fish which had not been so retarded during their eyed egg stage. Such did not appear to be the case, however, when appying the two common indices of growth determination; namely, average weight and average length. A representative sample of the population in each trough was weighed and measured at approximately monthly intervals. The results are given in tables #3 and #4.

Unfortunately, it was impossible to keep records on the quantity of food consumed by the various lots of fish during experimentation; hence, no information is available concerning the relative efficiency of their food conversion. It is possible that, although the retarded fish did quickly catch up with those not so retarded, they may have required more food to do so. However, the point is of less interest than the fact that the retarded fish did actually regain their normal growth.

CONCLUSIONS

In consideration of the facts uncovered in this gross experimentation, it would appear that the exposure to low temperatures undergone by eyed eggs during the course of ordinary egg shipments is in no demonstrable way injurious to those eggs. Although the hatching period of eggs so treated will be somewhat delayed, the fish produced will be under no subsequent handicap and will quickly regain their retarded growth under favorable conditions. Thus the rate of growth of fish would appear to be an inherent factor which is not materially altered by minor temporary adversities.

At times, undue losses do occur among eggs which have been shipped. However, these experiments would indicate that the primary cause for such losses is some factor other than the low temperatures involved.

TABLE 3. AVERAGE WEIGHT PER FISH (IN GRAMS)

	Trough Number							
	17	18	19	20	21	22	23	24
Days iced	0	2	4	6	8	10	12	14
Jan. 31 (sac-fry)	.22	.18	.17	.25	.3	.2	.22	.31
Feb. 21	.4	.41	.42	.4	.4	.41	.39	.41
Mar. 21	.5	.51	.54	.53	.45	.49	.56	.48

TABLE 4. AVERAGE LENGTH OF FISH (IN MILLIMETERS)

	17	18	19	20	21	22	23	24
Days iced	0	2	4	6	8	10	12	14
Jan. 31 - (sac-fry)	27.9							28.8
Feb. 21	31.4	31.1	30.9	30.8	30.8	31.3	30.7	31.7
Mar. 21	35.9	36.3	37.1	36.7	34.5	37.5	37.2	36.3

F I N G E R L I N G T R O U T-F E E D I N G

E X P E R I M E N T S, L E E T O W N, 1 9 3 8

By Dr. James S. Gutsell, U. S. Bureau of Fisheries

IN CARRYING ON the Bureau's established program of study of improved diets for trout, six series of fingerling feeding experiments were carried out at the experimental hatchery, Leetown, W. Va., in 1938. In all of these but that devoted to overfeeding, the trout were fed to the same dry basis; i.e., the dry weight of the food per day was the same percent of the weight of the fish at the latest weighing no matter how wet and bulky or dry and concentrated the diet might be. For experiments involving different proportions of dry feeds, this is very different from feeding the various lots equally on an "as weighed" or "as purchased" basis and leads to quite different results.

OUTLINE OF FEEDING EXPERIMENTS WITH FINGERLING TROUT

Except for those being intentionally overfed, all lots were fed to the same dry basis; ie., the dry weight of the food (assuming 70 percent moisture in liver, 66-2/3 percent in ground, sprouted seeds and 10 percent in meals and other "dry" feeds) per day was the same percent of the weight of the fish at the latest weighing no matter how wet and bulky or dry and concentrated the diet might be. In general, the weighings were bi-weekly. About 500 rainbow trout fingerlings were used per experiment; at first in half a trough, later in a whole trough. Except for experiments on the effect of sprouted seeds, experiments were begun May 12 (with previous feeding continued for a few days) and fed through October 24.

Standard dry mixture - Equal parts of meat meal, white fish meal, salmon egg meal, and dry buttermilk.

The liver used was sheep liver. The fish meal was vacuum dried from cod and haddock waste.

A. EFFECT OF OVERFEEDING:

No. 1a - All 150 rainbow trout fingerlings would take of combinations of liver and standard dry mixture. At first 70 percent liver and 30 percent dry mixture; later at 60 percent liver and 40 percent dry mixture.

No. 1b - Repeated with 151 brook trout fingerlings in other half of trough (positions of two species alternated after each weighing - generally at bi-weekly intervals).

B. EFFECT OF VARIOUS PROPORTIONS OF DRY FEEDS:

No. 2 - Liver 80 percent, standard dry mixture 20 percent.

No. 3 - Liver 70 percent, standard fry mixture 30 percent.

No. 4 - Liver 60 per cent, standard dry mixture 40 per cent.

No. 5 - Liver 50 percent, standard dry mixture 50 percent.

No. 6 - Liver 40 percent, standard dry mixture 60 percent.

C. COMPARISON OF CERTAIN DRY FEEDS:

At first 30 percent, later 40 percent, dry feed, balance liver.

No. 7 - Salmon carcass meal.

No. 8 - Seal meal.

No. 9 - Salmon egg meal.

No. 10 - Bio-Vita, high protein

No. 11 - Fish meal.

D. EFFECT OF ADDITION OF COD LIVER OIL TO DIET CONTAINING LARGE PROPORTION OF DRY FEED:

No. 12 - Three percent of cod liver oil; of the remaining 97 percent, at first seven parts were liver and three parts fish meal; later six parts liver and four parts fish meal.

E. COMPARISON OF EFFECTS OF KELP AND ALFALFA MEALS:

No. 13 - Five percent of kelp meal; of the remaining 95 percent, three parts were liver, one part fish meal.

No. 14 - Five percent of alfalfa meal; of the remaining 95 percent, three parts were liver, one part fish meal.

F. EFFECT OF SPROUTING SEEDS (July 20 to October 24):
(All items were fed to the same assumed dry basis. Sprouted seeds were fed from the same lots of seeds as those ground dry)

No. 15 - Liver 33.33 percent, fish meal 16.67 percent, sprouted wheat 50 percent.

No. 16 - Liver 50 percent, fish meal 25 percent, ground wheat 25 percent.

No. 17 - Liver 33.33 percent, fish meal 16.67 percent, sprouted soy beans 50 percent.

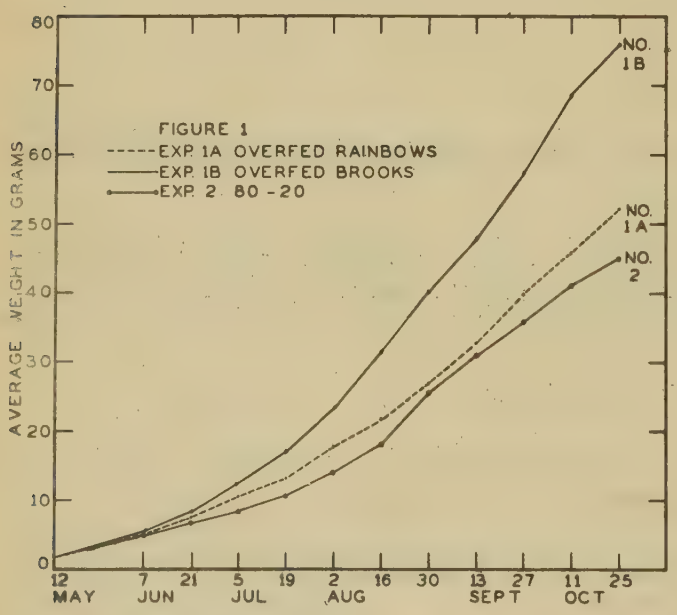
No. 18 - Liver 50 percent, fish meal 25 percent, ground soy beans 25 percent.

EXPERIMENTAL RESULTS

A. OVERFEEDING:

Principally to test the possible pathological effect of over-feeding, brook and rainbow fingerlings were fed about all they would take. One hundred and fifty-one brook trout fingerlings were placed in half a trough and 150 rainbows in the other half. After such weighing, the two overfed lots were alternated in position in the trough.

As in the next series of experiments, a combination of liver and a "standard dry mixture" or "4-meals" was fed. This standard dry mixture consisted of equal weights of meat meal, fish meal, salmon egg meal and dry buttermilk. 1/ The combination in this case consisted of 70 percent liver and 30 percent meals until July 19, when it was changed to 60 percent liver with 40 percent meals.



Feeding was begun with 10 percent ("as weighed") of the weight of the fish, increased to 15 percent, dropped to 12.5 percent, then to 9.26 percent (5 percent - dry basis), then to 7.41 percent (4 percent -dry basis), then to 6 percent, at which level it was continued for eight weeks, and finally to 5.5 percent about 3 percent - dry basis).

The principal results from the over-feeding experiment within the period covered by this report 2/ may be found in Figure 1. The brook trout, lot No. 16, (76 gms) although starting smaller, greatly outdistanced the rainbow trout, lot No. 1a, (51.7 gms), but the overfed rainbows were markedly heavier than any of the "normally fed" fish (heaviest 44.8 gms).

With the brook trout, 3.613 pounds of feed at a cost of $0.2844 were required to produce a pound of fish; with the rainbows the conversion was somewhat poorer, 3.874 pounds at a cost of $0.3065.

1/ From August 3 to October 17, the dry mixture used in this and the next series consisted of equal weights of meat meal, fish meal, and dried buttermilk.

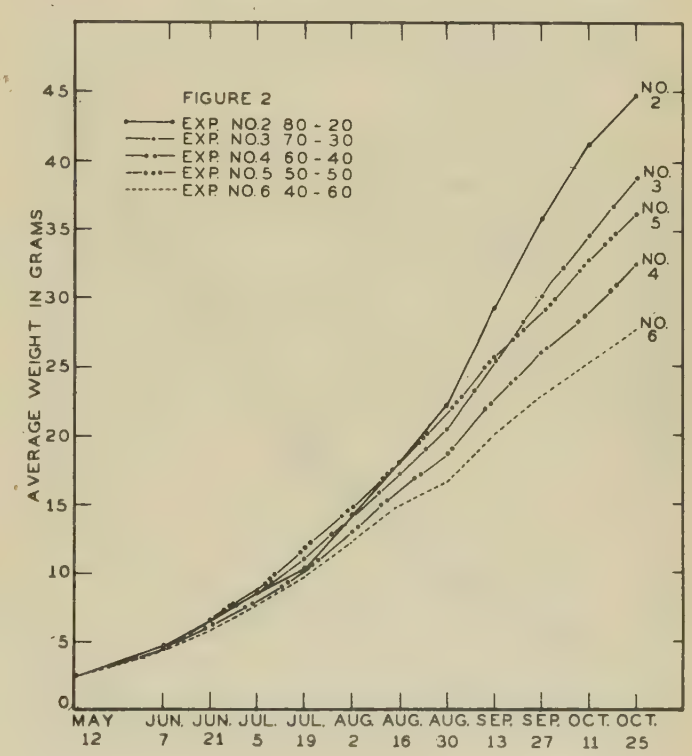
2/ This experiment is being continued to determine if pathologic conditions become important after a longer period, perhaps to one year of overfeeding.

None of the rainbows died and only one of the brooks.

B. EFFECT OF DIFFERENT PROPORTIONS OF DRY FEED:

This series consisted of lots fed varying percents of liver and "standard dry mixture" respectively as follows: 80-20, 70-30, 60-40, 50-50, and 40-60.

The lots were intended to be given "normal" feeding. It was supposed that this would consist of three-fourths of the amount (dry basis) given the overfed lots. The initial amount on a dry basis was 3.5 percent. On June 7 this was increased to 5 percent; June 21 reduced to 4 percent; July 19, to 3.5 percent; July 22, to 3 percent; August 16 to 2.5 percent; and October 11, to 2.3 percent.

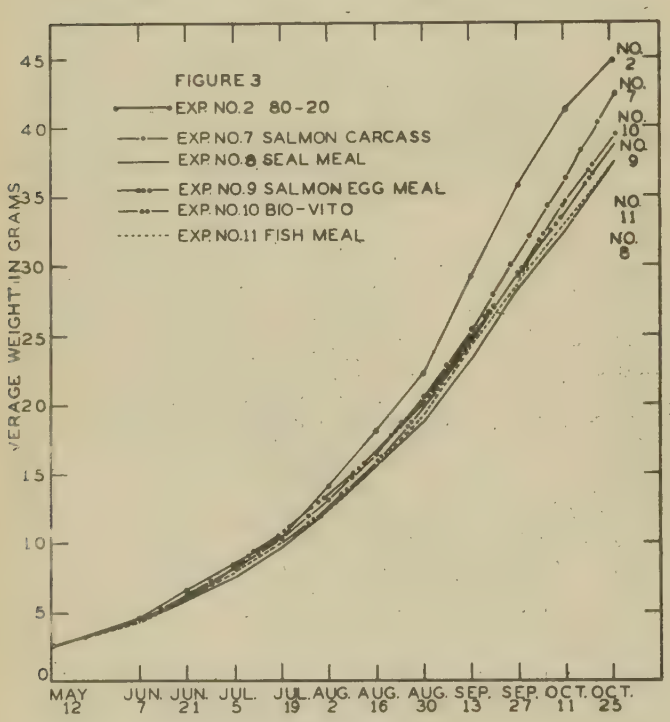


To the writer's surprise, the most rapid growing lot was, for a considerable period, that receiving the 50-50 mixture, lot No. 5. It was not until after August 16 that this lot was passed by any others of the series. Up to about this time it fed exceptionally well and seemed the prize lot of all. It ended in third place. Aside from this lot, the position was according to the proportion of meal in the diet - the more liver, the greater the growth. Such an arrangement (except for the one lot "out of position") is one to be expected in such a series fed on a dry basis. (The reverse of what would be expected when feeding such a series of feeds on an "as weighed basis"). However, if we consider the series from the weight or cost of food to produce a pound of fish we find the high meat (80-20) diet, lot No. 2, in the poorest position and the low meat diet (40-60), lot No. 6, in the best ($0.337) as compared with $0.210 per pound). The 70-30 lot No. 3 made a good growth at considerably less cost than the 80-20 lot. The growth of the low meat-high meal (40-60) lot No. 6, was definitely poor. (See Fig. 2).

It is evident from these experiments that the conversion of fresh meat is better than of dry feeds; but that, with a dry feed of moderate price, the cost of feeding becomes less as the proportion of dry food increases.

There was some undetermined trouble or troubles apparent among these lots and possibly present in others. Octomitus, which was prevalent in the hatchery, was suspected, and all the experimental lots were fed calomel. In addition, two of the lots (60-40 and 40-60) were dipped in a copper sulphate solution on suspicion of bacterial gill disease. In both cases the mortality ceased, and in each of these two cases, the mortality for the same bi-weekly period involved was 18. Aside from these, the greatest mortality was three (neglecting the loss of 290 in the 80-20 lot due to water stoppage). The 60-40 lot suffered only one additional loss, but the 40-60 lost seven in other periods. This increased loss with the poor growth may be taken to support the evidence that 60 percent is too much meal.

C. COMPARISON OF CERTAIN DRY FEEDS:



The dry feeds compared in this series were salmon carcass meal and seal meal (two Bureau products), the salmon egg meal purchased for general hatchery feeding, high protein Bio-Vita, and fish meal (white fish meal, vacuum dried from cod and haddock waste). While the fish were small they were fed only 30 percent meal. In July this was changed to 40 percent, in general conforming with the hatchery practice of increasing the proportion of dry feed as fingerling grow.

In growth, the lot No. 7 fed salmon carcass meal was well in the lead (average 42 gms), (see Fig. 3) followed by Bio-Vita, lot No. 10, (39.3 gms), the samlon egg meal, lot No. 9, (38.6 gms), fish meal, lot No. 11 (37.3 gms) and seal meal, lot No. 8, (37.2 gms). None of the lots made a notably poor growth and only the lot fed salmon carcass made a distinctly good one.

In cost of food to produce a pound of fish, the lot fed seal meal was best ($0.2018), closely followed by that fed salmon carcass meal ($0.2212) and fish meal ($0.2338). Because of the high prices involved, the lots fed salmon eggs products were expensive: Bio-Vita cost $0.3002 and "salmon egg meal" $0.386 to produce pound of fish.

Mortality varied from one to three among the lots of this series.

None of the rainbows died and only one of the brooks.

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This series consisted of lots fed varying percents of liver and "standard dry mixture" respectively as follows: 80-20, 70-30, 60-40, 50-50, and 40-60.

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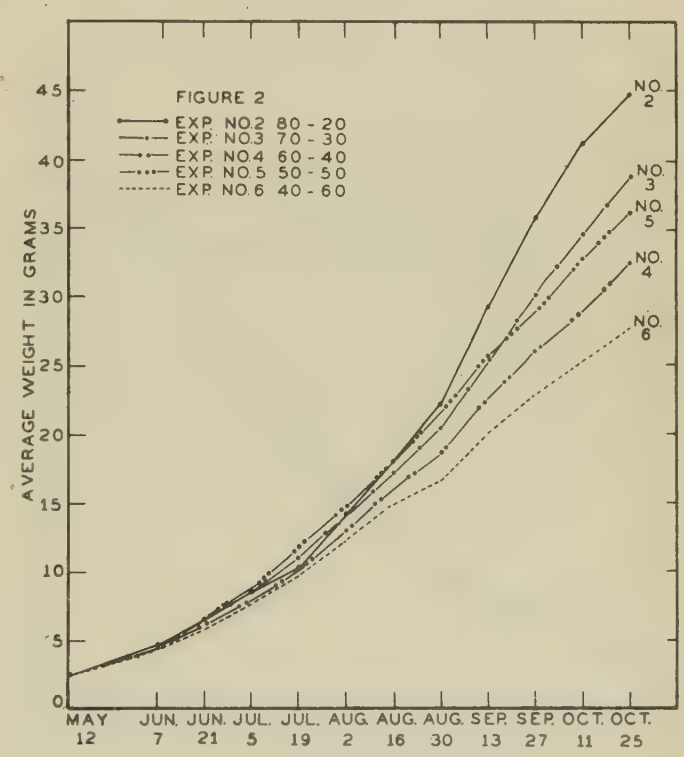

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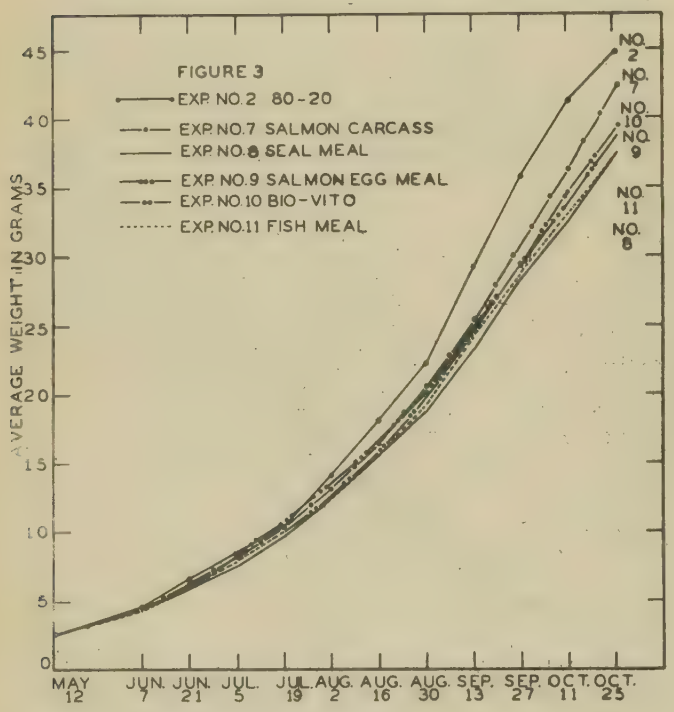

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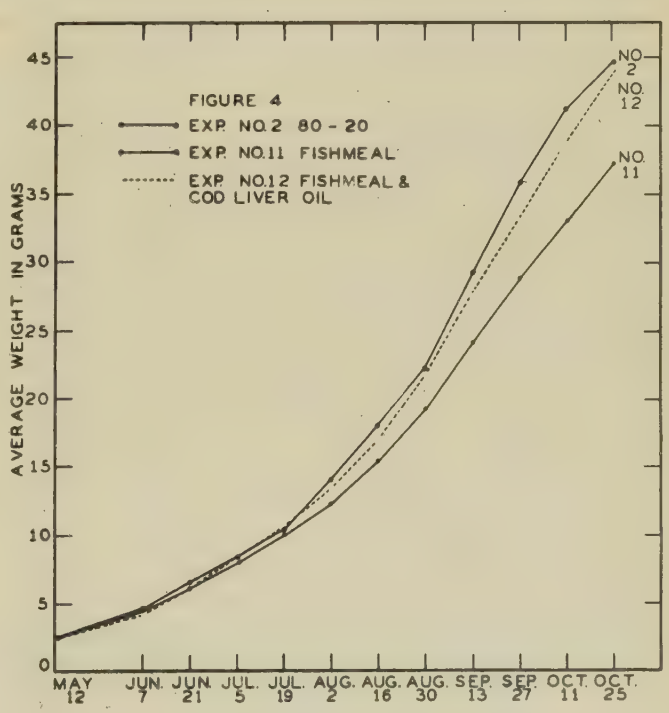
Mortality varied from one to three among the lots of this series.

D. EFFECT OF ADDITION OF COD LIVER OIL TO DIET CONTAINING LARGE PROPORTION OF DRY FEED (FISH MEAL):

In this experiment (No. 12) 3 percent of cod liver oil, commercial grade, was included. The remainder (97 percent) was divided between liver and fish meal as in the fish meal diet of the preceding series. The difference between the lot fed liver, fish meal and cod liver oil and that fed liver and fish meal (see Fig. 4) was quite remarkable. Whereas the latter was grouped with the seal meal lot at the foot of the series, the former made a better growth (average 44 gms) not only than any of that series but also better than any of the "normally fed" fish except the 80-20 lot (44.8 gms), and from the trend of the curves might soon have passed that.

In pounds of food to produce a pound of fish (conversion factor) this lot surpassed all with only 2.775 pounds required. In cost of food to produce a pound of fish ($0.2124) it was more than 2 cents below the same diet without cod liver oil and was bettered only by the seal meal diet and that containing 25 percent ground wheat.

Taking everything into consideration, this diet may be considered outstanding among all used this season.



E. COMPARISON OF KELP AND ALFALFA MEALS:

This series comprised only two experiments. Perhaps unfortunately they were designed only for comparison one with the other. Five percent of these meals were employed. The balance consisted of three-fourths liver and one-fourth fish meal.

The growth of the lot No. 14 fed alfalfa meal and 71.25 percent liver was decidedly low (average 36.8 gms), below that for the lot fed 40 percent meal through the time of principal growth and at no time more than 70 percent liver.

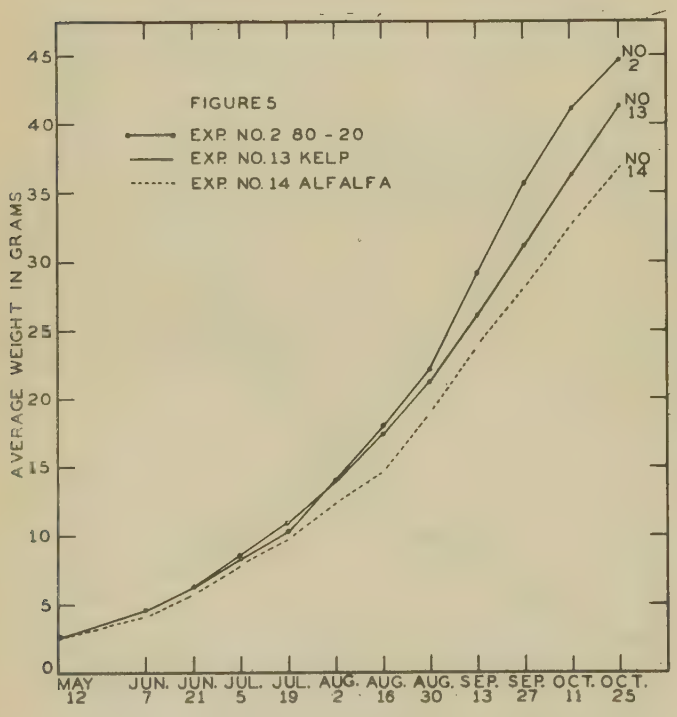
The lot No. 13 fed kelp meal did much better (average 41.3 gms - see Fig. 5) but how much of this good growth was due to the kelp and how much to the high (71.25) percent of liver, the writer feels uncertain.

In pounds of feed required to produce a pound of fish both were rather high, as was to be expected of a high meat diet, but surprisingly close together. The amount for the diet containing alfalfa was 3.467 pounds and for that containing kelp, 3.41 pounds. The cost of food to produce a pound of fish also was rather high, $0.2759 for the alfalfa diet, $0.274 for the kelp diet.

Two deaths were recorded for each lot.

F. EFFECT OF SPROUTING SEEDS:

Because of the increased vitamin content and conversion of starch into sugar produced by sprouting seeds and the possibility that this would make such material valuable as fish food, this series was undertaken with wheat and soy beans. The controls consisted of 50 percent liver, 25 percent fish meal, and 25 percent meal from the unsprouted seeds, ground locally from the same lot of seeds used for sprouting. Experiments indicated the sprouted seeds after being put through the meat grinder consisted of about two parts water to one part of solids, which was assumed in calculating the amounts to be fed. The grains and other constituents were calculated to the same dry basis as in the controls. Because a meat grider might not break up the sprouted grains into small enough particles for small fingerlings, these experiments were not started until July.



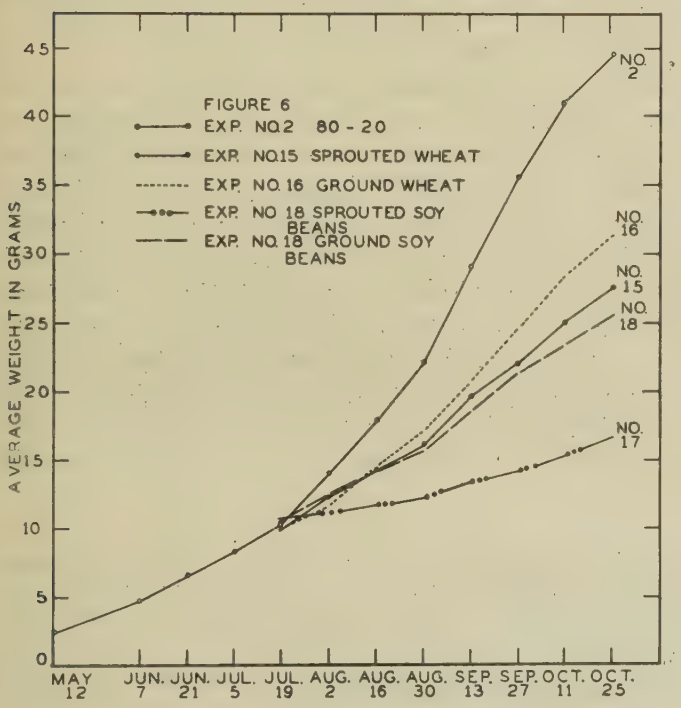
In growth, these four lots were much the poorest of all the experimental lots, and of these lots, the poorest was No. 17 fed sprouted soy beans (see Fig. 6). Moreover in each case the lot fed sprouted grain made less growth than the lot fed the unsprouted grain. The fish fed sprouted wheat, lot No. 15, averaged 27.5 gms; unsprouted, lot No. 16, 31.4 gms, sprouted soy beans, lot No. 17, 16.7 gms; unsprouted beans, lot No. 18, 25.7 gms.

The sprouting of the soy beans involved not only a considerable amount of work but also so much loss of beans that the product, as weighed out for mixing in the diet, cost for material 5 cents a pound. The wheat involved not only decidedly less trouble but also no noticeable loss in sprouting. Because of the work of mice, it was impracticable to determine the actual cost of the sprouted wheat, but, with wheat

at 75 cents a bushel, it was assumed to be $0.0142 per pound. This in part will explain the great difference in cost figures given in the next paragraph.

The diet containing sprouting wheat required 5.256 pounds to produce a pound of fish; that containing ground wheat, 3.278 pounds; that containing sprouted soy beans, 12.376 pounds; and that containing ground soy beans, 3.951 pounds. The cost of food to produce a pound of fish for sprouted wheat diet was $0.2345; for the ground wheat diet, $0.2047; for the sprouted soy beans, 10.7869; and for the ground soy beans, $0.2684.

Thus the sprouted soy bean diet was least productive and most expensive for the little growth obtained. The ground or unsprouted wheat produced a rather poor growth, but was almost as low as any in the cost of food to produce a pound of fish.



These lots suffered no loss for which an infectious disease was suspected. Only three deaths were recorded in the lot fed sprouted wheat, whereas against that fed unsprouted wheat ten were recorded. Mortality in the lots fed soy beans was higher than in most lots - seven recorded for No. 17 (sprouted) and five for No. 18.

SUMMARY AND DISCUSSION

Except for the overfeeding, these experiments were only with rainbow trout and involved about 500 fish each, at first in half a trough, later in the full trough.

The overfeeding experiments are chiefly notable for the good growth, good appearance and low mortality among the fish; i.e., for lack of obvious pathogenic effect; and for the decidedly more rapid growth of the brook trout (see Fig. 1).

The experiments with the various proportions of dry food are generally in accord with a hypothesis that fresh meat is more efficiently converted than is dry food. One lot, fed half liver and half dry feed, was out of line (see Fig. 2). Apparently this was principally due to the exceptional vigor and appetite which this lot early developed and which (coupled with the high early level of feeding) for the time made it, except for the overfed lots, the most rapid growing experimental lot. Later this stopped and the growth was more what might have been expected. It finished in third

instead of fourth place. In experiments with such a series, but with feeding to an equal "as weighed" basis, quite opposite results are to be expected with greatst growth from diets with highest proportions of dry feed.

Among the commercial feeds and those prepared by the Bureau, the outstanding success for growth was the Bureau's salmon carcass meal (see Fig. 3). For economy it also ranked among the best of all the diets tried. At the assumed price, which included only freight from Quilcene, Washington, and which probably amounted to more than costs in Washington, this diet was, in this series, second in cheapness of fish production only to that including seal meal. The salmon egg products, high protein Bio-Vita and salmon egg meal produced a good growth but at too high a cost to be recommended as economical growth producers. White fish meal, vacuum dried from cod and haddock waste, was noticeably below these in growth production but very much the best of the straight commercial feeds here compared in cheapness of fish flesh production.

The greatly increased growth (see Fig. 4) together with notable reduction in cost of production obtained by adding 3 percent of commercial cod liver oil to the liver-fish meal diet of the above series was unexpected and is considered quite remarkable. As noted previously, with never as much as 70 percent liver and through the period of grestest growth with less than 60 percent, it produced growth almost equal to that produced by 80 percent liver, 20 percent meals, and at a cost of food per pound of fish produced of $0.2124 as compared with $0.339 for the high liver diet and approximately $0.30 for the commercial salmon egg products. On the basis of these experiments, a little cod liver oil with a liver-fish meal diet high in fish meal would be ranked as the best considering both cost and growth. Of course, the experiment should be repeated. Cod liver oil should also be tried with some other low priced commercial fish feed, perhaps meat meal, and possibly with salmon carcass meal among Bureau products.

The other special ingredients tried were kelp and alfalfa meals. It was planned also to feed fresh alfalfa, but no satisfactory method of preparing this for small fish was found. The diet containing alfalfa meal produced poor growth (see Fig. 5). Apparently this material is not relished by fish and in quantities as high as 5 percent reduces feeding. No compensating advantage is evident.

The same diet but with kelp meal replacing alfalfa meal produced excellent growth but not sufficiently great considering the high percent of liver to make it clear to the writer that the kelp was an important factor. It would be well to try again with less meat and with the same diet without the kelp, as a control.

The tests of sprouted seeds need not be discussed in detail. The diets containing sprouted wheat and sprouted soy beans were inferior to those fed these items unsprouted, both in growth (see Fig. 6) and in cheapness of fish flesh production. Apparently the sprouted soy bean material is not liked by the fish. The diet containing sprouted wheat was taken much more readily, which at least in part explains the superior results obtained with it.

Considerable difficulty was experienced in the experiments in finding the proper level of feeding. For a considerable time, the fingerlings took amounts which eventually had to be reduced greatly. Evidently there had been overfeeding.
From these and other experiments conducted this year, it appears that if widely varying proportions of meat are involved and if feeding is to be to an equal dry basis, the level of feeding should be determined by or for the lot whose diet contains the highest proportion of meat, or arbitrarily made low enough so that there will be no danger of overfeeding these lots. If the equal basis is to be "as weighed" instead of fry, then the danger of overfeeding would occur with the lots containing the largest proportion of dry feed.

It seems that a useful series of experiments would be one comparing several levels of feeding the same diet. Because of the variable feeding, growth and other characteristics of individual lots, even when selected from the same stock, it seems highly desirable that experiments be run in duplicate.

DIPLOSTOMIASIS, A HATCHERY DISEASE OF FRESH-WATER FISHES NEW TO NORTH AMERICA

By Eddy D. Palmer, Dartmouth College

AN EXTRAORDINARY disease appeared in the New Jersey State Hatchery at Hacketts-town during 1937 and 1938 which caused considerable damage to several species of fishes. The causative agent was found to be the late larval form (metacercaria) of one or perhaps more species of trematodes or flukes belonging to the family Strigei-dae. The diseased condition was evident in damage wrought by the larvae in the lens of the fish's eye. Blindness in severe cases brought about starvation and death.*

Although many investigators have reported Strigeid metacercarial infections in several North American fishes, there has been no mention in the literature up to the present time of a hatchery disease caused by these agents in this country. Plehn describes such a disease, due to infection with Diplostomum spathaseum, as being com-mon in European fish-farms (1).

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* I wish to express my sincere appreciation to Dr. Frank H. Connell, under whom this study was conducted, for his kind interest and help. Dr. George R. LaRue of-fered several very helpful suggestions on a preliminary draft of this paper. I wish to thank Mr. Robert A. Hayford for his cooperation in supplying the materials for study, and Mr. Charles O. Hayford for kindly furnishing laboratory facilities at the Hackettstown hatchery. Mr. T. L. Bartlemez also gave valuable assistance.

It is difficult to explain the epizootic under consideration. There is a possibility that a foreign parasite which is more suited to development under hatchery conditions than the American species may lately have been introduced into this country from Europe, through the agency of the sea-birds which serve as primary hosts. Trans-atlantic crossings by such birds are frequent, and many species of Strigeid-carrying sea-birds are cospecific on the two sides of the ocean (2). On the other hand, North American Strigeidae have been reported from two of the four species of fish involved in the present incident (3), and it seems likely that these domestic flukes may infect a wider group of fishes than is at present realized. Diplostomum spathaceum, which has been studied more carefully than other Strigeids, has been found to infect members of several families of European fishes, including all four of the present species (1,4). Both Blochmann (5) and VanHaitsma (6) emphasize the fact that Strigeid cercariae lack a well defined host specificity. Because the birds that spread the flukes are notorious wanderers and their ranges cover practically all of North America (2), explanation of this sudden and unprecedented epizootic by an indigenous parasite presents some difficulties.

Identity and Morphology

The specific identity of the causative agent has not been determined. Several species of larval Strigeids have been reported from the eyes of fresh-water fishes. It is possible that more than one species may be involved in the present case. Since several host species may harbor a single parasite species, exact identification will help but little in indicating the possible sources of infection.*

The metacercariae were roughly oval and transparent, as the accompanying photomicrograph (Fig. 1) shows. A pair of ear-like lobes flanked the mouth at the anterior end. Two suckers, one surrounding the mouth and the other two-thirds back, were easily seen. Directly behind the posterior sucker lay the large oval haft-organ, an auxiliary attachment organ. The forked gut was usually prominent. In flattened specimens many scattered refractile spheres, the calacareous corpuscles, were seen, especially along the edges. Activity was expressed in great stretching movements.

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*It is obvious to anyone who has studied the Strigeidae that many species which have been described and apparently accepted by the authorities in the field are differentiable only on the vaguest morphological grounds. Camera-lucida drawings of the reserve excretory system as well as the grosser morphology of living metacercariae from the lens of a rainbow trout agreed very closely with Komiya's figures of Diplostomun spatchaceum (7). A herring gull, Larus argentatus, shot at Hackettstown during the period of infection contained about 100 adult Strigeids which appeared to fit Krause's description (8) of the adult of the same worm. But, as the figures in the literature attest and as VanHaitsma has emphasized (6), the arrangement of the vessels of the reserve excretory system in the metacercaria can no longer be taken as a diagnostic point in identifying members of this much subdivided group. Likewise, by comparing the descriptions of two Diplostomum species (6,p. 490; 9,p.30), it is found that there must at times be wider variation between two individuals of the same species than there is described as occurring between two separate species.

Specimens fixed in acid sublimate measured 0.3 to 0.38 mm. in length and 0.15 to 0.25 mm. in width.

Hosts

Snails serve as the first intermediate host and are necessary for the development of Strigeid flukes. Many of the common genera are involved in this function. Strangely enough, attempts to find infected snails at Hackettstown have not yet been successful.

Strigeid metacercariae have been reported from many groups of fishes, including the minnows, perches, bass, suckers, sunfishes, and rainbow trout. At Hackettstown

Fig. 1 Heavily infected lens from a rainbow trout teased apart to show the metacercariae as they appear under the low power of the compound microscope.

the flukes were found in brown and rainbow trout, bluegill sunfish, and common sucker.

Infection is spread by birds harboring the adults. Strigeid-infected birds which may visit hatcheries are the kingfisher, herring gull, laughing gull, great black-backed gull, great blue herron, parasitic jaeger, American merganser, kitti-

wake, Caspian tern, and probably many others. Herring gulls were found infected at Hackettstown. Two mallard ducks were found negative, and an attempt to infect a domestic duck proved unsuccessful. Twelve rainbow trout eyes containing many active metacercariae were fed, but fecal examinations proved negative for two and a half months, after which a careful sea.ch th ough the gut failed to eveal any worms.

Infection

Infection is a straightforward matter involving no carriers, infectable food, nor any other insidios mechanism. The fish plays a purely passive role. Infection is only possible when the fish is held in water containing snails infected with the early larval forms. The disease cannot be transmitted directly from fish to fish, nor from full to fish.

The course of the disease as it was observed at Hacketttown was very regular. Infection appeared suddenly, and all fish of a susceptible species in a pond became equally diseased and remained so. There was no recovery. Infection did not necessarily pass from pond to pond.

The rainbow was found to be very much more susceptible than the brown trout, a surprising condition in view of the fact that several quite unrelated fishes may harbor a single Strigeid species. During the fall of 1938, 1500 two-year brown and 1500 rainbow trout of the same age were held in a dirt pond. Infection took place, and all the fish were sorted. It was found that every rainbow harbored metacercariae, while less than a dozen of the browns were infected.

Life Cycle of the Parasite

Complete details of the life cycle of American Strigeidae have not been worked out. LaRue summarizes the cycle of a typical Streigeid as follows (10):

Eggs pass from the bird with the feces and hatch in the water. The resulting free-swimming larvae (miracidia) must, in order to continue development, penetrate within a few hours into certain snails. In the snail complex development and multiplication go on. The redia stage is omitted. Forked-tail cercariae with pharynges and at least two pairs of cephalic glands are produced by daughter sporocysts. If the cercariae, while swimming rapidly about, come in contact with certain species of fish, they bore through the skin, losing their tails in the process. The worms can evidently wander through the tissues of the host, but only those which finally find the eye survive. These make their way into the lens where they metamorphose into metacercariae. The worms do not encyst but remain active in the lens; this is the stage directly responsible for damage to the fish. In the present case penetration of the cercariae had no apparent effect on the fish; often the entrance of large numbers of certain species of Strigeids cause the death of the host (5,6).

Birds acquire the infection by eating the fish or their eyes. According to VanHaitsma (9), maturation of the Strigeidae in the intestines of birds takes rapidly,

often within a week. Each adult produces a small number of large eggs.

Pathology and Symptomatology

Damage done by the metacercariae was primarily limited to the fish's eye. Secondarily, food-taking was often interrupted. Death from the disease was always due to starvation.

The effect of infection on the eye was marked. In about one-third of the cases there was hemorrhage from the iris, probably caused by cercariae entering the eye at an angle and passing through this structure. The worms tended to gather in the peripheral layers of the lens next to the pupil, the invaded area becoming liquefied and whitened. Very few larvae were seen in the humors; apparently they appear here only during migration. A few worms did not seem to hinder vision, but in heavy infections the lens was reduced to a white cheesy mass. One hundred seventy was the greatest number of metacercariae counted in a single trout lens.

In lightly infected sectioned material the lens capsule seemed whole and not pathologically altered. The layer of lenticular tissue immediately under the capsule was atrophied around the whole lens. The larvae, however, were closely grouped at the pupil. Plehn (1) states that the lens may break up and be absorbed, and that it often becomes displaced and may even wander through the pupil, bulging out the cornea. No such cases were seen in the present investigation.

Trout with relatively light infections remained healthy. The stomachs and intestines of trout whose lenses held 30 to 40 metacercariae were usually full. Such fish were accurate and vigorous in feeding. Fish with white lenses invariably starved, but did not seem to become less resistant to other hatchery diseases. No secondary bacterial or fungal infection of the pierced body was noted, although Plehn (1) found abundant fungus growth in many cases.

Diagnosis

Diagnosis is an easy matter. The presence of a diseased condition is advertised by a whitening of the center of the eye. The procedure is merely to tease apart the lense in a drop of water on a slide. The active larvae are quickly picked up under the low power of the compound microscope. They can, in fact, be seen against black background with the unaided eye. Diagnosis can be made on the whole fish with the aid of a low power dissecting microscope or a hand lens. Until more is learned of the species of Strigeids which are actually present among hatchery fish in this country, closer examination of the parasite will not be necessary. Further knowledge along this line may help by indicating the species of birds which must be controlled in fighting the disease.

Prognosis

Unless routine examination is practiced at the hatchery, light infections will not be noticed. The danger in this situation is that, when the disease does become evident, it will be too late to help the diseased fish. A light general infection

does no appreciable harm at the moment, but it may spread the parasites to so many fish-eating birds that after the infection is again passed to the fish, whole colonies may be wiped out. Thus prognosis is good in light cases, but such cases are the basis for future disastrous epizootics.

Treatment

No known treatment is applicable.

Prophylaxis

Prophylaxis consists of destroying infected snails, fish, and birds. Persistence is required to keep a hatchery free of snails and birds. The carrying of cercariae from pool to pool is not important in spreading the disease. The axiom that crowding the fish increases infection, however, remains valid in this case.

All species of snails in all ponds are destroyed in fighting the disease. This is effectively accomplished by any of the methods ordinarily used in disinfecting ponds; drying, however, is of no value. The use of liquid chlorine has been very effective at Hackettstown.

Infected fish should be burned or buried.

Several hatchery birds may be involved in spreading infection. There is a constant war being waged against fish-eating birds at most hatcheries; any progress in this direction will help reduce infection.

References

(1) Plehn, M. 1924 - Practicum der Fischkrankheiten. Stutt. pp. 447-448, 7 figs.

(2) Forbush, E. H. 1925 - Birds of Massachusetts and Other New England States. Mass. Dept. of Agriculture, vol. 1

(3) Many authors, including
Hughes, R. C. 1928 - Trans. Am. Micr. Soc., vol. XLVII, No. 3, July 1928, pp. 320-334

VanHaitsma, J. P. 1931 - Papers, Mich. Acad. Sci., Arts, Letters, vol. XIII, pp. 483-516

(4) Braun, M. 1892 - Bronn's Klass. u. Ordnung d.Thier-Reichs, Leipz., vol. 4, Abt.1a,Lief 18-27

(5) Blochmann, F. 1910 - Centralk.f.Bakt., I Abt., Orig., 56 (Heft 11), pp. 47-49

(6) VanHaitsma, J. P. 1931 - Papers, Mich. Acad. Sci., Arts, Letters, vol. XIII, pp. 483-512

(7) Komiya, Y. 1938 - Zeitsch.f.Parasitenk.,10.Band, 3.Heft, pp. 340-385

(8) Krause, R. 1915 - Zeitschr. f. Wissensch. Zool, vol. 112, pp. 93-238

(9) LaRue, G.R. 1927 - Trans., Am. Micr. Soc., vol. XLVI, No. 1, Jan. 1927, pp. 26-31

(10) LaRue, G.R. 1926 - idem. vol. XLV, No. 4, Oct. 1926, pp. 265-277

FURUNCULOSIS AND ANOTHER CASE OF ICHTHYOPHTHIRIASIS

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IN THE NOVEMBER-DECEMBER, 1938, issue of THE PROGRESSIVE FISH CULTURIST there appeared an article by Dr. Louis E. Wolf concerning an out break of ichthyophthiriasis, apparently the first known record of this disease reaching serious proportions in an American trout hatchery. Last season, 1938, the fish of the Cowichan lake hatchery suffered an attack of this disease following an epidemic of furunculosis, both of which resulted in heavy losses among both trout and Pacific salmon (Oncorhynchus). This also seems to be a new record for the disease ichthyophthiriasis since there appears to be no reference to its occurrence in any other hatchery in this province. Moreover, there appears to be no record of this disease attacking fingerlings of the Pacific salmon. Therefore, it seems worthwhile to record the occurrence of ichthyophthiriasis among both trout and salmon held in a British Columbia hatchery in the hope that the information may be of help in preventing its occurrence in other establishments.

The set-up at the hatchery is apparently much like that at the State Fish Hatchery, Rome, N. Y. as described by Wolf in that the ponds are arranged in series, the upper series draining into the lower and in that the water supply is taken from two sources, a small mountain stream and a large river. Water conditions, particularly temperature, must have differed considerably however. Dr. Wolf gives the Rome hatchery water temperature as 52° F. but does not mention the temperature of the ponds where the disease occured. Presumably the pond temperature was higher than 52° since the water was a mixture of spring and lake water. At the Cowichan lake hatchery the pond temperature reached a maximum of 70° F. early in July and ranged between 62° and 68° F. during most of the epidemic period. The ponds contained five

species of fish at this time. Three of the upper series of six ponds contained steelhead (rainbow) fingerlings, and three contained spring (king) salmon fingerlings. The lower series of six ponds contained fingerlings of cutthroat and brown trout and coho (silver) salmon so arranged that the cutthroats and browns received water from the steelhead ponds and the cohos received water from the spring ponds.

The first indications of trouble became evident among the spring and coho fingerlings during the first week in July when numbers of the fish began to die for no apparent reason. Within a few days a number of the afflicted fish bore blue colored patches on the side of the body and losses increased at an alarming rate, at first among the springs but later also among the cohos in the lower ponds. The fish were examined on August 2 by Dr. D. C. B. Duff, consulting pathologist of the Station, and cultures of Bacillus salmonicida were obtained from dying fish, proving that both springs and cohos were suffering from furunculosis. Positive evidence of the presence of this disease among steelhead, cutthroat and brown trout in the remaining tanks was not obtained at this time but later the typical lesions began to appear among them also and losses were very high. It would seem that furunculosis was present in each of the 12 retaining ponds and that each species of fish had suffered from the disease. The weekly losses during the peak of the furunculosis epidemic ranged from 10 to 24 percent for the springs, 10 to 16 percent for the cohos, 10 to 14 percent for the steelhead, 11 to 35 percent for the browns, and 8 to 29 percent for the cutthroats. The time and extent of these losses are shown in Table 2, which gives the weekly mortalities as percent loss based upon the number of fish of each species on hand at the beginning of each week.

Table 1. Weekly percent loss of Cowichan lake hatchery stock, based upon number of fish present at beginning of each week

Week ending	Springs (60,000)	Coho (60,000)	Steelhead (60,000)	Brown (15,000)	Cutthroat (15,000)
	Percent	Percent	Percent	Percent	Percent
June 4	0.5	0.4	2.2	12.1	1.3
" 11	0.2	0.4	1.8	10.9	0.8
" 18	0.3	0.3	2.7	11.2	1.6
" 25	0.3	0.2	3.4	8.9	6.9
July 2	1.1	0.5	14.3	35.4	29.1
" 9	3.1	0.6	12.5	11.3	21.4
" 16	4.3	1.8	10.2	2.7	8.7
" 23	22.8	10.5	12.2	1.5	8.5
" 30	10.8	16.8	12.2	1.2	3.0
Aug. 6	19.0	12.0	11.8	1.9	3.3
" 13	24.2	5.5	3.6	1.7	2.0
" 20	5.6	3.2	43.1	6.9	28.9
" 27	2.6	1.8	35.3	19.2	15.9
Sept. 3	2.3	1.3	13.7	4.4	0.9
" 10	1.3	0.7	7.6	0.3	0.1
" 17	1.9	0.5	1.3	0.1	0.1

When a disease as serious as furunculosis is discovered in a hatchery two courses of action are open; either the entire hatchery stock may be destroyed and the plant thoroughly disinfected or the infected fish may be retained and cared for in the hope that some may be saved and the year's work not entirely lost. The latter course was chosen because it was felt that some fish were better than no fish and particularly because it was desired to study the history of this disease. For example, in the case of the spring and coho salmon which were to be marked before release there was some chance of retaking a few of them as adults thus allowing the investigation of the possibility of the disease surviving a salt-water phase in the life history of the infected fish. The stock was therefore retained and everything possible done to reduce the severity of the losses. This included isolating the infected tanks by using separate water supplies, removing all dead and dying fish several times a day and increasing the fresh meat component of the diet. Except for copper sulphate dips which were used to no avail before the disease was recognized no direct treatments of the infected fish were attempted.

Following these heavy losses due to furunculosis the mortality rate for all the fish dropped during the week ending August 13 but rose quickly again to a new peak, this time among the trout only. During this period the cause of loss seemed to be due mainly to Ichthyophthirius since most of the afflicated fish were found to be carrying a heavy infestation of this parasite. The steelheads were the most heaviy infected while the cutthroats and browns, which received water from the steelhead ponds, were also heavily infected but to a lesser extent. The spring and coho salmon did not escape attack entirely but they appeared to be less seriously affected since losses were much lower than in the case of the trout. The period during which the fish were visibly infected extended over several weeks and losses continued to occur until about the middle of September when the water temperature had dropped to 62° F.

Several means were tried to help rid the fish of the parasite causing this disease. Daily salt bath treatments were given to one group of fish over a period of a week and the rate of flow of water was increased by lowering the pond level but no benefit was evident. It would seem from these results and from the experience of others that once the protozoan is established on the fish the control methods commonly used for external parasites are of little or no avail. This is to be expected since it has been demonstrated by Wolf that the parasite is imbedded in the host beneath the epidermis where chemicals in the water cannot penetrate.

With regard to the origin of these diseases in the Cowichan lake hatchery, nothing is positively known. Since this is the first season that these diseases have been recorded among the stock of this establishment and since this is the first season that a portion of the water supply was obtained from the river, it is natural to suspect this stream as being the source of the trouble. Conditions were no doubt particularly favorable since the water temperatures were probably higher than during any other year in the history of the hatchery, due to the fact that the river water was much warmer than that of the small stream used in previous seasons for supplying the ponds. The river water was tempered by mixing with the cooler water of the stream but nevertheless the temperatures attained were still higher than desirable for fish held under hatchery conditions, with the result that the introduction of the disease-

producing organisms, which normally would have caused little or no loss, resulted in a severe epidemic.

The foregoing brief account contributes nothing new to the fish culturists' knowledge of these diseases except to indicate that they are probably more common in nature than is generally supposed and that under favorable conditions, such as may be found in a hatchery, the organisms causing these diseases are capable of producing epidemics which may result in heavy losses of fish. Therefore, when a hatchery water supply is taken from a stream known to contain fish, the appearance of disease among the hatchery stock should be watched for or better still, precautions should be taken to avoid the occurrence of disease and parasites in general by the installation of a means of disinfecting or filtering the water supply before use. Such a means of control is proposed for the Cowichan lake hatchery.

A N O T H E R H A T C H E R Y M E A T-R O O M

By Robert Fortney,
District Supervisor of Fisheries Operation
Michigan Department of Conservation

ONE DAY during the summer of 1936 I went into the old meat-room at the Paris Hatchery and assisted Barney Engle, a Senior Fish Culturist, in charge of preparation of trout diet and feeding, to grind and prepare the trout diets for three rearing stations, which are a part of the Paris system.

We lifted and dumped 36 cans of food into the grinder-hopper and then lifted and dumped each can three times more before the food particles were small enough for the small size trout in the stations at that time. Each can filled with food weighed 60 lbs. so we lifted and handled a combined weight of 8,640 lbs. before the operations were completed.

The meat-room, at that time, was housed in an old wooden building. Pungent, nauseating odors emanated from the sidewalls and floor. Huge rats came out of their hiding places to look askance at us for interrupting their raids on food supplies.

We both speculated at the time if ever there would come an opportunity to rebuild modern, ratproof, meat-rooms and with equipment to take some of the curse out of preparing trout diets.

The Paris Hatchery was completely rebuilt during the biennium of 1937-1938, and at the outset of building operations we decided to incorporate in the plans for the meat-room and refrigerator room, certain improvements of a more or less revolutionary character which would facilitate the preparation of trout diets.

The building, which houses the food room and refrigerator room, is of reinforced concrete, including the roof, which is flat, with a slight slope on top to carry off the waters of rain and melted snow. A paved road encircles the hatchery building proper thus enabling heavy trucks to leave supplies at the meat-room door.

The inside dimensions of the meat-room are 15'3" long by 12'11" wide and 12' 6" high. The inside dimensions of the refrigerator room are 12'5" long by 7'5" wide and 7'8" high.

The inside dimensions of the wash tank, which is of reinforced concrete construction, are 5' long by 3'3" wide by 2'2" deep. The cutting table and grinder base are also of reinforced concrete construction and were built as one unit with the wash tank. As the grinder base narrows down to 25" wide, the cutting table curves out to join the outer end of the wash tank. The combined length of the cutting table and grinder base is 5' and it is the same height as the wash tank (2'2").

The meat-room is equipped with a standard dairy barn litter carrier equipment. The circular track hangers were embedded in the concrete of the roof when it was poured. Each of the heavy galvanized steel tubs have a food capacity of 720 lbs. and are known to dairymen as 12 bushel tubs.

The 6" valves, which are mounted in the center and bottom of the tubs are not standard equipment. They were made by a blacksmith out of 6" galvanized pipe and 1/4" boiler plate. He did such a good job, the valve is water tight. The inside ends of the tubs are also made sloping, by means of heavy sheet metal strips, soldered to the sides of the tubs.

In grinding and mixing food for the Paris Hatcheries and associated rearing stations, the method of procedure is as follows:

One of the tubs is placed on a low wooden frame, which can be moved about, because the frame is provided with heavy duty casters. The tub is then placed directly under the grinder. A grinder plate with 1" holes is used for the first operation. The sheep liver and hogmelts are forked into the grinder-hopper; ground fish and cereal are now added, in layers, and mixed very briefly with an old fashioned garden rake equipped with a short handle. This process is continued until the hopper is full. To feed our adult trout the mixture is run but once through the grinder, equipped with the one inch plate and the size of the food particles are perfect for adult trout. For the smaller trout in rearing stations, we also start out with the 1" plate and then the mixture is run as high as four times through smaller plates until the food particles are the right size.

As the trout become larger in the Rearing Stations, once through the one inch plate and then once more through a smaller plate is sufficient.

We increased the efficiency of our food grinder and speeded up the time of operation by merely increasing the R.P.M. of the grinder. Formerly we ran our grinder 400 R.P.M. and now it runs 600 R.P.M. which seems to us to be about right.

In preparing food for rearing stations, we have saved a lot of heavy lifting by building a table holding 12 food cans equipped with heavy duty casters. We merely valve off the food into the cans and roll the table out to the truck. The table top is the same height as the truck floor and it is an easy matter to slide the cans onto the truck. Often the food is ground the afternoon before it is transferred to rearing stations. Cans are filled on the table and it is rolled into the refrigerator room and the food kept cold until the following morning.

Hot and cold water under pressure and a gravity flow of cold water are available for meat-room use. The valves are mounted just above the wash tank. A hose is kept in a rack, just above the hot and cold water valves and ready for attachment.

General view of the Paris Hatchery meat-room
showing grinder, hoist, and meat tubs

The concrete floor slopes toward the middle of the room and an 8" drain is provided to carry off water and wastes. The ceiling, sidewalls, and floor may be flushed down with a hose and kept in a clean and sanitary condition. The meat-room and refrigerator room are absolutely ratproof. Even the wooden doors are lined with heavy metal for a distance of 3' from the floor.

Sometime in the future we hope to add an electric hoist to our meat room equipment for hoisting the tubs into position above the grinder and for valving off the food. When this has been accomplished we shall feel that our most troublesome and perplexing problem related to fish culture at the Paris Hatchery has been solved.

COMMENTS FROM OUR READERS

FORAGE FISH, LILY CONTROL AND SNAPPING TURTLES

EDITOR, THE PROGRESSIVE FISH CULTURIST:

Up to now, being merely a tyro (and knowing it), I have just listened and learned and, like probably 90% of your readers, hardly expected ever to contribute to the PROGRESSIVE FISH CULTURIST. However, this plea from fellow lake-owner A. C. Playfair, of Chewelah, Washington, appearing in Number 43 of OUR SHEET loosens my tongue and unlimbers my typewriter, for apparently he's in my boat and maybe my experience will answer his question No. 2: Advisability of putting forage fish into a trout lake now stocked with adult fish used as spawners.

It is a well-known fact that stream trout, including the brook trout and rainbows of Wisconsin, Michigan, Minnesota, and Canada, which go down in late spring to the Great Lakes, come back packing plenty of "heft" or "meat." Such trout are known hereabouts as "coasters." I am told that their greater weight and size is largely due to the superabundance of minnows they find in, particularly, Lake Superior and Lake Michigan.

Using this information and upon the recommendation of State hatchery men, we stocked our lake (or springhole) and stream with all the forage minnows we could obtain with most satisfactory results. Our experience is, the bigger the trout, the more he likes minnow diet.

We put most stress, of course, on the different species which already were established, such as shiners, chubs, and suckers (I expect a kickback from your readers on that one, but I'm prepared to give them an argument), and after a year or more of trying to obtain a few specimens of stickleback for brood stock, we gave up in disgust only to find that they, too, were native to our waters.

After five years of observation, however, I am inclined to recommend that chubs be eliminated from such a forage fish stocking program, as they grow to a fair size and themselves compete for food with the trout. And here's a word of warning: Be sure that each species is provided with the means to maintain itself, and by that I do not mean only food supply. Favorable spawning conditions, if not naturally present, must be provided artificially if your trout are to continue getting "fat 'n' sassy" on forage fish.

Regarding water lily control, the only mechanical control I know of, is MUSK-RATS! They'll eat the leaf or pad, the stem, and even uproot and sample the big, pineapple-like tuber. We have quite a few of the critters, and in direct proportion to their increase, I've noticed a definite shrinkage of water lily beds! We bless the little so-and-so's---until they start chewing on our prized plantings of willows!

Our big problem is turtles,--particularly snapping turtls. Can someone please tell us how to trap them?

Cassius Winkelman
Wasau, Wisconsin

A NEW WATER AERATOR

EDITOR, THE PROGRESSIVE FISH CULTURIST:

My first knowledge that fish, as well as that ourselves, cannot exist without oxygen came many years ago during my father's first attempt to plant fish--hauling them in cans for twenty-five miles with a wagon and team. This was before the automobile. I was a small boy then, and could not undrestand why so many of the fish died. I have been greatly interested in hatcheries and fish distribution ever since, especially with reference to the aeration, or oxygenation, of water.

Not much change has been made in modes of aeration equipment. Compressed air through a filter has been used, also oxygen tanks, which in many instances, have proven that they require too much knowledge and care in getting the exact amount of oxygen in the water, to sustain, without killing the fish. Pumps which pump the water through jets, under pressure, drawing the water from the bottom of the tank and squirting it back upon the surface, have also been used. These and similar arrangements seem to be more or less standard.

Because of the shortcomings of all of these methods, I have felt that there must be a better way, so I began to reason that if a swift stream with a rocky bottom could so easily retain a high oxygen content, why not cause the bottom of the tank, transportation tank or otherwise, to move swiftly under the water, reversely simulating nature, introducing air at the bottom of the tank at the same time, which would be broken up by some sort of projection or other.

I have tried many different arrangements to attain this end, but most of them proved to be too cumbersome; however, I finally arrived at the use of a high speed rotor operating at the bottom of the tank, which operates with a small power

requirement, and which has been operated satisfactorily in water to a depth of five feet.

The machine has a tubular shaft extending to either the surface of the tank, or through its bottom, where the driving means is attached. The rotor is rotated by the shaft in a horizontal plane very close to the bottom of the tank, and has an outward extending arm on each side. These arms are also tubular, and connected with the hollow shaft, leaving a continuous air passage through the shaft and arms. The arms are provided at their outer ends with a very thin knife-like extension, which cuts through the water at a high rate of speed, causing a vacuum to be formed at their trailing edges, which are grooved.

When these arms rotate at sufficient speed, the centrifugal force generated within them frees them of water and air flows out at their open ends where the knife-life extension begins. The groove on the trailing edge of this extension is supplied with air by the vacuum caused by its rapid forward motion, drawing the air behind it, not unlike the air which will follow behind a stick or rod swung rapidly back and forth through water.

My problem was to provide a means of supplying air at the bottom of the tank for these blades to break up, which was arrived at by connecting the hollow shaft to the rotating arms and rotating them at sufficient speed to eject the water within them, automatically introducing air by the centrifugal force generated, alone.

When this machine is operated in a tank at sufficient speed, the water becomes so clouded with minute air bubbles that it is impossible to see an object on the bottom of the tank, even in as little as one foot of perfectly clear water.

Each blade is slightly curved backward from the end of the arm, which causes the air to flow outward to its tip, and also causes an answering outward current to be formed in the water at the bottom of the tank, and strangely, this current does not rise, but follows the bottom of the tank until it reaches the edge, where it is, especially in a rectangular tank, broken up and rises. The surface flows toward the machine and then down through it and along the bottom of the tank, thereby creating a full circulation throughout the entire tank, in which there is no still, or dead water.

The driving means for this machine may be any motor such as electric, gasoline, etc. A power take off from a truck, driving the machine through a flexible shaft, would be logical for a truck transportation unit and, in fact, a machine such as was demonstrated at the Bozeman Hatchery has been successfully operated by the power taken from the fan belt of my automobile.

The machine has but one moving part, the follow tube and rotor, which is a part of it.

Considerable testing and experimenting has been necessary, and in the last of these tests, conducted at the Federal Fish Hatcher at Bozeman, Montana, on March 8, the following results were had:

Time	Temperature F.	Oxygen ppm.	% Saturation
10:00 A. M.	52	8.3	75
12:00 M.	---	6.3	---
1:00 P. M.	---	7.0	---
3:00 P. M.	64	6.7	70
3:45 P. M.	54	7.6	70
4:10 P. M.	58	7.3	71
4:20 P. M.	52	7.9	71

Water in the tank was 16 inches deep, amounting to 88 gallons. It held 488 ounces of four-inch fish, or thirty and one-half pounds. Oxygen tests were conducted by personnel of Bozeman hatchery and Mr. Hagen of the Seattle office.

It should be noted that the test was continuous for six hours, and that when they were removed the fish appeared to be in excellent condition; however, when temperatures became high, they were plainly in distress, and a few were lost at that time. I did not jot down the number lost but recall it as twelve. It is further significant that at the end of the six hour test we had rebuilt the oxygen to a point approximating that at which we began, and that the last two tests were made at intervals of ten minutes, at which time we had restored the original temperature.

No cooling arrangement was attached to this particular machine and temperature was brought down by the addition of snow, but I have found that if chilled air is introduced through the machine, it is so thoroughly disseminated throughout the tank, in these millions of minute bubbles, that it is more effective than the addition of ice to the water.

This machine should maintain the best possible results in railroad car transportation and can easily be applied to the hatchery supply by installing a rotor having a sufficient number of arms on the hollow shaft, which would be mounted within the supply mains, with its end extending outside for the application of the driving means, in which case the air is thoroughly broken up inside the supply pipe itself.

An open pool is as easily aerated as a tank.

With this machine it is possible to approximate hatchery trough conditions in fish transportation tanks loaded with fish in normal or better loads and, from experience already had, it is not too much to say that these conditions can be maintained indefinitely, making it possible to transport fish in a crowded condition for long distances.

Lorin Lefevre
Great Falls, Montana

NOTES AND NEWS

MEXICO TRAINS CONSERVATION WORKERS

The Bureau has just received an announcement from the Department of Forests, Game and Fish of the Republic of Mexico with reference to the establishment of a new institution for training forest engineers and technicians in game and fish management. The announcement briefly states that the new establishment is located in the National Forest Reserve in the State of Vera Cruz in a mountainous section with access to various lakes and coastal waters. A building has been provided for a school center. The Mexican Government is to be congratulated for the wisdom displayed in making a start toward building up a trained corps of forestry, game and fisheries workers.

MEXICAN TROUT AGAIN INTRODUCED INTO CALIFORNIA

It will be recalled that THE PROGRESSIVE FISH CULTURIST No. 38 of May, 1938, p. 18, carried news of the loss of the first lot of fifty-five yearling Salmo nelsoni that were introduced into California from Mexico in late spring of 1937. Floods of March 2 and 3, 1938, in Southern California, wrecked the Forest Home Hatchery and destroyed both eggs and adults being held there.

Between May 8 and May 18, 1939, another trip was made to the Santo Domingo River in Baja California, Mexico, to secure another lot of these fish alive. Dr. P. R. Needham and Dr. Osgood R. Smith of the Bureau of Fisheries were accompanied by two U. S. Forest Service men, Ivan Sack of the Division of Wildlife Management, San Francisco, and J. B. Stephenson, District Ranger, Cleveland National Forest, San Diego. Aerating equipment and fish cans were loaned by the California Division of Fish and Game.

The trip was most successful in all respects. A total of 325 Salmo nelsoni were taken out alive without loss. Of this number, 311 were fish of the year or fingerlings, around two inches in length, and 14 were yearlings, averaging around five inches. At present they are all being held and fed at the Convict Creek Experi--mental Stream near Bishop in eastern California. Later this summer they will be split up into either two or three lots for rearing and spawning at separate hatcheries. Once sufficient offspring are obtained, experiments will be conducted with them to determine: (1) Migratory habits, (2) tolerance to high temperatures, and (3) changes that take place following domestication in hatcheries.

The only untoward event that occurred was bending the crank-case of Fisheries Truck No. 219 on a high center in the road which, needless to say, was nothing finer than a magnified cow-path. Fortunately, Mr. Stephenson of the Forest Service happened to have a set of socket wrenches along, so the men were able to take the crankcase off for straightening. A local Mexican miner who, by another lucky chance, happened to have a forge and anvil heated the case red-hot and pounded it back into shape. After placing it back in the car, it fitted perfectly, no oil leaks showing anywhere. It was fortunate, too, that this accident occurred enroute to the Santo Domingo River before the live trout had been obtained.

OVERCROWDING TROUT

By Lowell A. Woodbury, Junior Biologist
Wisconsin Conservation Department, Madison, Wisconsin

(Reprinted with permission from Wisconsin FISHERIES
BIOLOGICAL BULLETIN, Nov. 7, 1938, No. 10)

Fish culturists are of the opinion that overcrowding of fish in rearing troughs, raceways and ponds is an undesirable condition in the hatchery. However, there is a diversity of opinion as to what constitutes overcrowding. Much discussion has taken place on this subject, but as yet no definite conclusions have been reached. Two reasons for this state of affairs are that, first, conditions are different in every locality and overcrowding in one locality may be normal in another. Second, no one knows exactly what overcrowding is except as a general impression that there are too many fish in a trough.

The following criteria may be used, however, in determining when overcrowding exists. If two or more of the following conditions prevail, overcrowding may be said to exist:

1. The oxygen content of the water passing over the fish drops to a dangerously low level for best health.

2. The free carbon dioxide of the water rises to a high value, probably 10 to 25 ppm.

3. The fish are so crowded in the troughs that some are not able to obtain sufficient food resulting in an excessively high number of runts.

4. The loss is excessively high probably over 1 or 2 percent per month.

5. The fish are extremely susceptible to disease as compared with troughs with a lesser population.

6. The rate of growth is poor.

It must not be thought that all of these factors must be present before overcrowding can be presumed to occur. The presence of any two of the above is extremely suggestive of overcrowding, although in determining in any particular locality what constitutes this condition, information on all of the above points is helpful.

Perhaps one of the most convincing illustrations of what overcrowding can do is to compare the growth rate of trout in troughs having identical conditions except for the number of fish per trough. This was done at the Wild Rose trout hatchery recently through the kind cooperation of Mr. Cliff Hills and Mr. Paige Nicholls.

Four standard troughs were chosen and set up as follows:

Trough No.	Species	No. of Fish per trough	Average No. of Fish per pound	Average Weight Grams
1	Brown Trout	2,000	302.5	1.5
2	" "	4,600	330.0	1.4
3	" "	7,200	312.5	1.4
4	" "	10,000	338.0	1.3

This experiment was initiated on August 16, 1938 and carried through to October 22, 1938, a total of 67 days. The fish were fed as much as they would clean up each day of the following mixture: ground canned carp, ground raw liver, milk. The fish were weighed at approximately two week intervals. Losses were recorded daily.

TABLE I. WEIGHT IN POUNDS OF 1,000 FISH, INCREASE, LOSS, AND TOTAL PRODUCTION WITH VARYING DEGREES OF CROWDING

	Number of Fish per Trough			
	2,000	4,600	7,200	10,000
Aug. 16	3.30	3.03	3.20	2.96
Aug. 31	4.44	3.82	3.67	3.78
Sept. 14	5.10	4.75	4.64	4.03
Sept. 28	5.78	5.35	5.18	4.85
Oct. 12	9.01	7.87	6.76	6.17
Oct. 22	9.01	7.90	6.97	6.51
Percent Increase	173.0	160.7	117.8	119.9
Percent Loss	0.6	.043	1.13	0.79
Total Pounds Fish Produced	17.9	36.2	49.6	64.6

The results of the experiment are shown in Table I from which it can be seen that the trout in the trough containing the least number of fish had the best growth, while the trout in the trough containing the largest number of fish had the least rapid growth. The percentage losses are too small to permit any definite conclusions being formed on this basis. The somewhat higher loss from the tank containing 7,200 fish may be attributed to a slight amount of cannibalism which seemed to be present.

The most obvious conclusion from this experiment is that the smaller the number of fish per trough, all other conditions being equal, the larger the fish will grow in a given time. Reference, however, to the bottom row of Table I will show that although the trough with the largest number of fish present produced the least growth of individual fish, it produced the greatest number of pounds of fish.

The problem is where to draw the line. The object of the fish culturists at the hatchery is to raise as many fish as possible, as large as possible, and in the shortest time possible in the allotted space of his hatchery. There is no definite answer as to the optimum number of fish per trough that can be given beforehand. It is something that must be worked out at each hatchetry for all sizes of fish, as obviously overcrowding may not exist with a given number of one size of fish, and may be serious with the same number of another size of fish.

It is planned, now that we know better what to look for, to set up an experiment at each hatchery to determine just what constitutes overcrowding and the optimum number of fish of different sizes that can be placed in a cubic foot of water to produce the best results relative to growth, health, and cost.

REVIEWS

ON METHODICAL LIBERATIONS OF SALMON AND TROUT FRY IN WATER COURSES WITH SPECIAL REFERENCES TO THE GUDENAA AREA

By C. W. Otterstrom

Report of the Danish Biological Station to the Ministry of Agriculture and Fisheries. XLII, 1937, pp. 3-32, 21 figures. Copenhagen.

This paper is of considerable interest to those interested in fish management since it is the result of detailed studies on Danish trout streams carried on over a

period of years for the purpose of developing a stocking policy. These streams support a considerable population of salmon and sea trout, both, of course, migratory fish which spend the larger part of their existence in the sea and tidal waters. Many of the Danish streams are now barred to ascending migrants by dams, pollution and other obstacles so that if the headwaters are to be utilized by young trout and salmon, they must be stocked artificially.

Owing to the expense of rearing trout to yearling or larger sizes, only fry are used for stocking in most cases although "half-yearlings" are planted in some of the larger streams. As a justification for the use of fry, the author points to statistical studies which showed that the liberation of 10,000 fry yielded an additional catch of 14 summer salmon while the liberation of 10,000 "half-yearlings" only increased the catch by 19 fish.

The thoroughness with which the stocking plans have been worked out will be of special interest to American fish culturists. The fry are transported in special milk cans with a container for ice. Each can has a capacity of about 32 quarts and will carry from 2,500 to 5,000 fry for six hours at 8° C. Aeration with compressed air has not proved successful.

It will no doubt startle some fish culturists to learn that ordinarily no attention is paid to tempering the water when planting, since investigations by Alm and others have shown that fish are highly indifferent to sudden changes in temperature. Only liberation into very cold water (below 5° C) or very warm water (above 25° C) is believed to be harmful to the fry.

On the other hand, great emphasis is placed on the importance of liberating fry only where stream conditions are favorable. Ideal localities are places where the bottom consists of gravel or pebbles which will afford shelter to the fry; where there is ample food and a moderate current and where the water is quite shallow (2-10 inches). These conditions are discussed in considerable detail and illustrated by photographs of various types of streams.

For stocking purposes the streams are divided into four groups as follows: (1) unsuitable, (2) usable but not good, (3) suitable and (4) pre-eminent. However, no definite criteria are set up for each group and the particular group to which each stream is allocated appears to be largely a matter of personal opinion. Streams classed as "suitable" are stocked at the rate of one fry per square meter, "usable" streams at the rate of one-half fry per square meter and "pre-eminent" streams at the rate of two fry per square meter.

The author points out that these figures are much lower than those formerly used but believes that they will yield better results. At this rate he estimates that in a stream classed as "suitable" there will be, at the end of the summer, one vigorous "half-yearling" for each 10 square meters.

Special emphasis is placed on the desirability of distributing the fry carefully, a matter which is considered of paramount importance on account of the many obstacles to the free movement of fish in Danish streams. In order to accomplish

this, plans for planting the fry of trout and salmon have been worked out in great detail. A map of the Gudenaa (a stream about 78 miles long) and its tributaries shows no less than 386 points designed as "places of liberation."

H. S. Davis

AUTO-ECOLOGY OF BROOK TROUT (SALVELINUS FONTINALIS) IN TWO PRIMITIVE STREAMS OF NORTHERN NEW HAMPSHIRE

By Earl E. Hoover, Deceased, and
G. W. Morrill, Jr.

Technical Circular - Brook Trout No. 2
New Hampshire Fish & Game Department

This circular is reviewed because it presents a number of findings and conclusions in startling contrast to the concepts which have become more or less firmly imbedded in the minds of anglers and many students of trout stream ecology.

The work is based upon the poisoning of two trout streams in the White Mountain National Forest, such action being necessary in order to elininate a furunculosis epidemic in the water supply of the York Pond, N. H., Hatchery. The streams had not been stocked for a number of years and were considered primitive according to present day standards. The virtually 100 percent poisoning and recovery of all fish life afforded a unique opportunity for a quantititative check on the population. The rather iconoclastic nature of some of the findings can best be shown by verbatim quotation without "ifs" or "buts" on the part of the reviewer:

"SUMMARY

"15 - There was no correlation between bank cover and trout production.

"16 - There was no correlation between fish shelter and trout production.

"18 - Trout stomach analysis studies from six streams in 1937 indicate that only 12% of the food in these streams is of aquatic origin. Investigators in New York and Vermont estimate 85% of the food should come from the stream bed.

"19 - As trout pounds per acre increase, insect food decreases. Indications are that bottom food is a poor production indicator.

"21 - All but the 2" size class of trout are adversely affected by riffle increase.

"24 - There is no variation in the ratio of size range distribution from source to mouth of a stream. Brook trout do not migrate downward as they increase in size or age.

"26 - The closing of small tributary streams does not result in the improvement of fishing in the main stream.

"28 - Fontinalis had no effect on stream productivity. Its chief value is in binding sand and fine gravel.

'30 - Individual comparison of data on width, depth, shelter and cover with production gives no correlation. These factors in combination do give correlation. They must be considered as a group to observe effect.

"CONCLUSIONS

"4 - Pounds or numbers per acre of bottom invertebrates are unreliable as production indicators.

"6 - There is some factor or combination of factors which is yet undiscovered. Until this is found, trout stream management will be crude."

It is possibly unfair to lift from the context of the entire paper individual statements like the foregoing. However, it is felt that they are sufficiently challenging to interest the gentlemen of the trade to induce them to obtain and read the entire paper.

M. C. James

LOWER COST DIETS FOR HATCHERY TROUT

By W. W. Aitken. Iowa State College Jour. Sc., 1938 Vol. XIII, No. 1, 27-33.

ABSTRACT

Feeding experiments were conducted with hatchery trout to determine the comparative value of three diets, namely: I, beef heart; II, beef heart 50 percent and ground cooked carp and buffalo 50 percent; and, III, ground cooked carp and buffalo. brook trout fingerlings confined in hatchery troughs were used in one set of experiments. The length of these experiments was 90 days. In another set of experiments larger fingerlings, brown trout, were held in raceways throughout an experimental period of 80 days.

The beef heart was trimmed and ground in the fresh condition. "The carp and buffalo were ground entire, cooked and packed in seven-pound cans. Buffalo too small to have a market value made up 80 percent of the ground fish and the other 20 percent was carp of four to five pounds in individual weight."

Records were kept on the amount of food fed to each test group of fish. From the periodic weighings of samples taken from the different lots (ten day intervals) the gain in weight of each group of fish was determined. Curves are presented to illustrate the gains of the respective groups and tables show the weight of food fed, weight of fish, and gain in weight of fish for each ten day period of the experiment.

Diet I proved to be the most expensive food for the brown trout fingerlings and III the most economical. The food cost per pound of brown trout fingerlings produced on the three diets was as follows: I, 25 cents; II, 18 cents; and III, 15 cents. No mortality was experienced in the brown trout experimental lots. The mortality in the case of the smaller size brook trout fingerlings was noticeably different for the groups of fish fed the three diets. Out of the 1,000 fish which started each experiment, 57 were lost on diet I, 160 on II, and 464 on III. In view of this mortality, III was not satisfactory for this size fish and even II might be held to be somewhat questionable.

A. V. Tunison

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(Continued from inside front cover)

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